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THE

GEOLOGICAL MAGAZINE

NEW SERIES. DECADE VI. VOL. IV.

No. I.—JANUARY, 1917.

ORIGINAL ARTICLES.

I.—Early Man.

By Arthur Smith Woodward, LL.D., F.R.S.

GEOLOGISTS and archæologists are much indebted to Professors Osborn and Obermaier [1] for useful up-to-date summaries of our knowledge of early man, with extensive bibliographies which include most of the latest papers. So much progress has been made in the study of the subject during recent years—especially since the Prince of Monaco's foundation of the Institute of Human Palæontology in Paris—that synoptical treatises of this kind are an indispensable aid to further advance. Both are also intended, with their beautiful illustrations, to arouse interest in a much wider circle than that of students who are actually engaged in research. They should, indeed, help in urging the educated public to take every opportunity of bringing to the notice of scientific men such casual discoveries of human remains and traces of human handiwork as they happen to meet with. It is lamentable to think how few of these discoveries, even under existing circumstances, are rescued from destruction and made available for study.

Both authors deal with the geological questions involved in determining the relative ages and circumstances of life of the successive races of men who inhabited Western Europe before the dawn of history. Professor Osborn, however, treats these questions at greatest length, and includes an elaborate summary of Penck & Brückner's work, *Die Alpen im Eiszeitalter*, with which he attempts to correlate all the European discoveries of Palæolithic man. He even goes further in assigning dates to the successive episodes which he recognizes, and we cannot refrain from protesting against the false appearance of knowledge which he thus provides for the unwary reader who does not understand geology. "Heidelberg man," Professor Osborn writes, "is nearly twice as ancient as the Piltdown man, while *Pithecanthropus* (Trinil Race) is four times as ancient. Yet the Piltdown man must still be regarded as of very great antiquity, for he is four times as ancient as the final type of Neanderthal man belonging to the Mousterian industrial stage." It is scarcely necessary to add that there is no real scientific basis for any of these statements.

All are agreed that among the remains usually claimed to be

[1] H. F. Osborn, *Men of the Old Stone Age—their Environment, Life, and Art*. New York, Charles Scribner's Sons, 1915 (2nd ed., 1916). H. Obermaier, *El Hombre Fósil*. Madrid, Comisión de Investigaciones Paleontológicas y Prehistóricas, Memoria No. 9, 1916.

connected with the early ancestry of man those of *Pithecanthropus erectus* from Java are probably the oldest hitherto discovered. Professors Osborn and Obermaier, however, differ considerably in their interpretation of this remarkable fossil species, the former regarding it as a lowly type of man, the latter treating it as a gigantic ape. The fact is that no further progress can be made in understanding *Pithecanthropus* until Professor Eugene Dubois publishes his long-promised detailed description of the cast of the brain-cavity which he has so beautifully prepared. During my last visit to Holland, in 1913, Professor Dubois kindly showed me all the original specimens with materials for comparison, and my own impression was that the resemblances to the gibbon which he has pointed out in each part are very real and striking. The upper molar teeth and the distal end of the femur, for example, have some remarkably gibbon-like characters. A detached lower premolar, it is true, is essentially human in type; but the fragment of mandible, from the same geological formation, so often mentioned in notices of *Pithecanthropus*, was found a few miles distant from the other remains and cannot at present be associated with them. This specimen is merely a waterworn piece of bone beneath the two premolars, which have lost their crowns; but, so far as preserved, it appears to be typically human. There is thus some reason to suspect that man himself lived in Java with *Pithecanthropus*, and that the latter was really a gigantic and precocious gibbon. The occurrence of such an animal in the large island of Java—the special home of gibbons—would be precisely analogous to the presence of the extinct gigantic and precocious lemurs in the swamps and caves of the large island of Madagascar—the special home of lemurs.

For some reason which I do not appreciate, Professor Osborn supposes that *Homo heidelbergensis* is next in antiquity to *Pithecanthropus*, while *Eoanthropus dawsoni* (Piltdown man) flourished much later. Such an opinion can only be founded on negative evidence, and the reverse is suggested by the characters of the lower jaw itself. *Eoanthropus* may have survived to become contemporary with Heidelberg man, but it can scarcely have had a later origin. Professor Osborn's own restoration of the skull and mandible of *Eoanthropus* (made with the help of Professor J. H. McGregor) is, indeed, essentially similar to the latest restorations made independently both by the British Museum and by the Royal College of Surgeons, and certainly represents the lowest human type hitherto discovered. Professor Osborn only mars his work by placing the canine tooth in the upper jaw, with no opposing tooth in the lower jaw which could produce its characteristic deep surface of wear. He also fails to recognize the fact that this canine tooth is more closely similar in shape to the lower milk-canine of *Homo sapiens* than to the canine, either upper or lower, whether temporary or permanent, of any known ape. In the second edition of his volume (without, however, altering the main part of the text) he seems to realize the difficulties of his position, and even adopts the strange opinion of Mr. Gerrit S. Miller,[1] that the Piltdown lower jaw and canine tooth do not

[1] G. S. Miller, *The Jaw of the Piltdown Man*, Smithson. Miscell. Collections, vol. lxv, No. 12, pp. 31, pls. v, 1915.

belong to the associated skull but represent a new species of chimpanzee. Mr. Miller does not recognize that the lower molar teeth are essentially human, and his arguments will soon be satisfactorily dealt with by Mr. W. P. Pycraft in *Science Progress*. I hope then to give some account of a discovery made by the late Mr. Charles Dawson shortly before his death, which appears to me to confirm the interpretation of *Eoanthropus* which he and I originally published in 1912.

All the mammalian remains found in the Piltdown gravel are in so fragmentary a condition, and several are so obviously derived from an older stratum, that they are insufficient to date *Eoanthropus* with exactness. Probably the only specimen of real importance from this point of view is the unique bone implement,[1] apparently made from the femur of an elephant which was too large for *Elephas primigenius*, but must have agreed in size with that of *E. antiquus* and *E. meridionalis*. In the Mauer sand, however, in which the lower jaw of *Homo heidelbergensis* was found, mammalian remains are abundant, and many of the specimens shown to me by Professor W. Salomon at Heidelberg in 1912 are in a remarkable state of preservation. As all palæontologists agree, this mammalian fauna must date back to a very early part of the Pleistocene period. The human lower jaw is in the same condition as the other remains, and is evidently of the same age. Compared with the Piltdown jaw it is typically human; but it differs from later human lower jaws both in the sharp retreat of the chin and in the incomplete bony filling of the ape-like pit on the inner face of the chin where the geniohyoid and geniohyoglossal muscles have their origin.

Since Professor Marcellin Boule's exhaustive memoir on the skeleton of La-Chapelle-aux-Saints (1911–13), nothing of importance has been added to our knowledge of Neanderthal man. Professor Schwalbe has described a lower jaw from Taubach, near Weimar (Germany), and Professor Obermaier makes known another from Bañolas, province of Gerona (Spain). This race, however, is now tolerably well known, while the associated implements and remains of the mammalian fauna are well represented in many collections. Both Professor Osborn and Professor Obermaier are able to give a good account of the circumstances of the Mousterian period during which Neanderthal man lived. There is no doubt that the comparatively genial conditions which surrounded Piltdown man and Heidelberg man had passed away, and that an Arctic fauna predominated.

The chief interest of later Palæolithic man centres, not in his skeleton, but in his artistic attainments; and a large proportion of the two new volumes before us is devoted to a beautifully illustrated account of the discoveries of later Palæolithic art in France and Spain. None but those who have seen them, however, can realize the extraordinary skill with which the drawings and paintings are made on the irregular surfaces of rock in the remote recesses of the

[1] C. Dawson & A. S. Woodward, "On a Bone Implement from Piltdown (Sussex)": Quart. Journ. Geol. Soc., vol. lxxi, pp. 144–8, pl. xiv, 1915.

caverns. While scrambling through the cavern of Castillo, near Puente Viesgo (Santander), with Mr. Alcalde del Rio in 1910, when its exploration had only been begun, my wife and I had the opportunity of appreciating, not only the skill of the Palæolithic artists, but also the patience of those who have during recent years made so many faithful copies of their work for publication. Professor Obermaier devotes two pages to a discussion of the authenticity of these drawings and paintings, which can only be necessary for readers who have not had the privilege of seeing and considering the originals.

It becomes increasingly clear that man did not reach America until he had attained the grade of *Homo sapiens*, and both Professor Osborn and Professor Obermaier omit the discussion of American fossil man from their story. It can merely be stated that there is evidence both in North and South America of the presence of typical man among the remains of Pleistocene mammals which are now extinct. An interesting case has lately been recorded in the United States.[1] In remote parts of the Old World, however, important discoveries of early man are more hopeful, for only so recently as 1914 a well-fossilized human skull was found in a river deposit containing Pleistocene mammals at Talgai in the Darling Downs, Queensland. It was exhibited to the British Association meeting in Sydney by Professor Edgeworth David and Professor Smith, and it is shortly to be described in a memoir submitted to the Royal Society of London. Photographs of the specimen were shown to the Geological Society of London on December 1, 1915.[2] Although in nearly every respect the skull of a typical Australian aborigine, this fossil agrees with *Eoanthropus* from Piltdown in having the relatively large canine teeth interlocking as in the apes, and it is the only known skull of *Homo* exhibiting this arrangement. The upper canines are typical permanent teeth merely enlarged and modified; the lower canines (still undiscovered) were therefore probably also of the permanent pattern, and thus differed from those of the more primitive *Eoanthropus* which, as already mentioned, are shaped like the modern human milk-teeth.

The unravelling of the story of early man is indeed a continual struggle with the fragmentary evidence of casual discoveries. Much of it still consists in the balancing of probabilities. The value of the influence of attractive summaries like those before us, adapted for the general reader as well as the specialist, cannot therefore be too highly estimated. No one can tell how and where their influence may preserve the next important discovery from thoughtless destruction.

[1] E. H. Sellards, "On the Discovery of Fossil Human Remains in Florida in association with Extinct Vertebrates": Amer. Journ. Sci. [4], vol. xlii, pp. 1–18, with figs., 1916.

[2] GEOL. MAG., Dec. VI, Vol. III, p. 44, January, 1916.

II.—Some Notes on the Post-Eocene and Post-Miocene Movements in the Oilfield Region of Egypt.

By William Fraser Hume, D.Sc., A.R.S.M., F.G.S., Director of the Geological Survey of Egypt.

IT may interest readers of the Geological Magazine to have a summarized account of the new data obtained regarding the Post-Eocene and Post-Miocene movements in the Gulf of Suez area, and notably in its southern portion, the oilfield region of Egypt (see Map, Fig. 1).

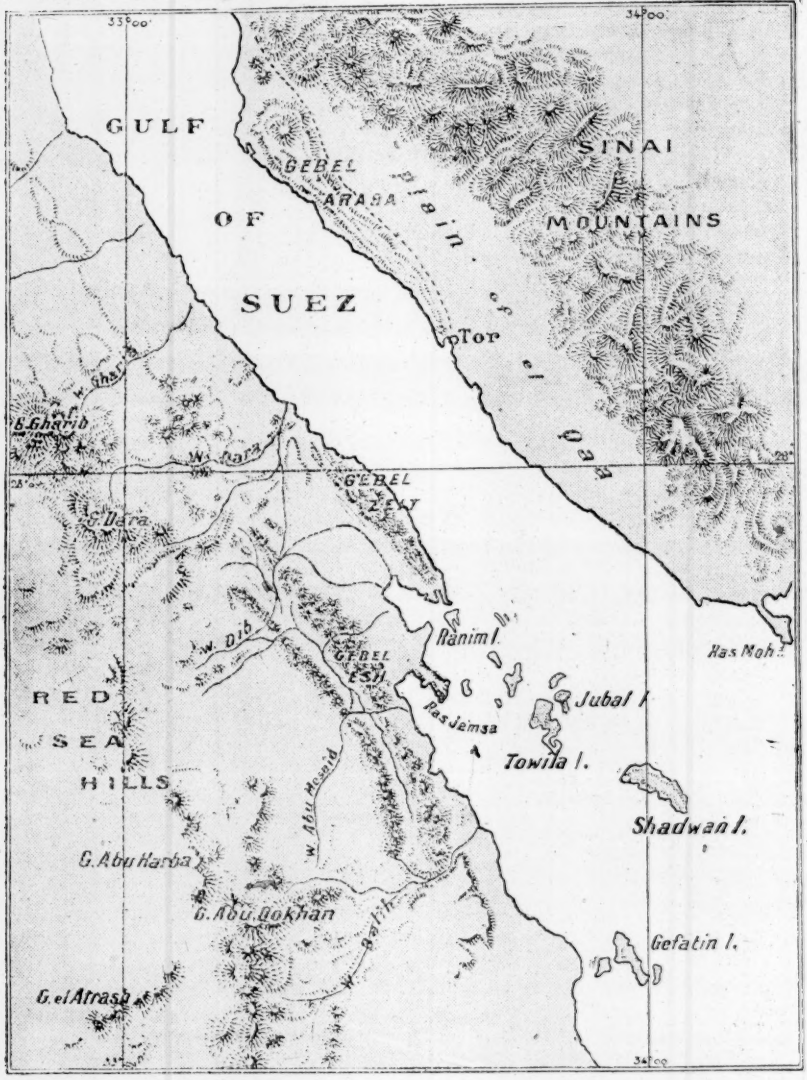
To understand the subsequent remarks it is necessary to have one or two fundamental conceptions, obtained from previous studies, well established in our minds. The first is the nature of the strata which were present in the region before folding began. Owing to the great depression of Cretaceous times a mass of limestones, clays, and sandstones were laid down on the old solid continental foundation of granites and metamorphic rocks. These soft sedimentary beds may have attained a thickness of at least 2,000 feet.

In the second place, folding at the close of the Cretaceous period (the nature of which is masked by subsequent events) led to the redistribution of much of the upper highly calcareous material, and no doubt supplied the carbonate of lime necessary for the shell-deposits, nummulitic beds, etc., of the Egyptian Eocene. These gave an additional 2,000 feet or more of strata, and it is thus possible that in the basin portions of the Post-Cretaceous fold the sedimentaries may be fully 4,000 feet thick as an average. When examining the total thickness of the Eocene and Cretaceous beds in Egypt for the "Explanatory Notes to accompany the Geological Map of Egypt" I found a maximum of 6,000 feet.

The great primary Egyptian fold is, however, undoubtedly the one which closed the Eocene Period. A glance at the geological map of Egypt exhibits to us the broad shallow synclinal basin of Central Egypt with N.W.–S.E. axis, and it needs but little imagination mentally to picture the corresponding anticline, the central axis of which would lie in the Gulf of Suez and Red Sea. We have thus a region of compression in Egypt proper, but one of tension where the Red Sea now is. In that of tension there would be tendency for the formation of a series of fractures parallel to and including one at the axis. It seems to me that the underlying harder granite-metamorphic complex will break more readily than the more plastic materials overlying it, the result being that spaces will be left beneath the sedimentaries into which these would naturally tend to sink. But in the rising anticline there will also be maximum erosion towards the central axis, so that the Eocene–Cretaceous sedimentaries will be greatly reduced or wholly disappear. The facts are clear enough.

Nearest the centre of the anticlinal axis, on Shadwan Island, for example, the Miocene beds rest directly against the granite, there being no sign of more ancient sedimentaries. In Gebel Zeit, slightly to the west of the probable axis, all the Eocene and uppermost Cretaceous beds have disappeared (being only shown to have existed

MAP OF EGYPTIAN OILFIELD REGION *Fig. 1*



by a flint conglomerate), but we find the Lower Cretaceous strata and Nubian Sandstone between the Miocene and the granite, whereas in Gebel Esh,[1] some 20 kilometres west of Gebel Zeit, the missing Eocene and Cretaceous beds are represented.

The broad space between the Red Sea Hills and Sinai Mountains would, on this view, have originated as the result of a combination of anticlinal fracture and erosion, acting on two media, the lower one of which was, in the main, hard and brittle, the upper one plastic and pliable. The above-mentioned ranges are themselves connected with dislocation-lines of the most pronounced type, the faulted borders in each case being on the sides towards the Gulf of Suez. At the close of the Lower Miocene period there appears to have been a general sinking, as a result of which the waters of the Mediterranean were enabled to invade the above-mentioned groove. The breadth of this greater Gulf of Suez appears to be at its maximum about 70 kilometres, and in it were laid down deeper-water strata, such as Globigerina Oozes, and also others in which various characteristic Miocene *Pecten* species predominate, whilst later these were overlain by a vast series of calcareous gypsum and salt deposits, which in places appear to attain thicknesses of at least 3,000 feet! (a thickness of 6,000 feet is suggested north of lat. 28° N., but the country has not been studied in detail).

The shore-lines of this Miocene arm are well defined by the presence of coral reefs and flint conglomerate beds, the latter representing the erosion of Eocene or Upper Cretaceous beds previously existing.

With the close of Miocene times this triple complex of Miocene beds, older sedimentaries preserved from erosion, and granite-metamorphic rock core, became subject to new compression by which the whole region was thrown into a series of N.W.–S.E. trending folds, in which the anticlines, asymmetrical in character, had their most steeply inclined sides directed towards the Gulf of Suez. Each of these anticlines has determined a well-marked physical feature, the Esh-Mellaha, Zeit, and Araba (in Sinai) Hills respectively. In the simplest case the relation of slope on the two flanks is about 1 to 3 or 4, the general dip on the less inclined limb being 8° to 10°, and on the more inclined one 25° to 35°. As already stated, the resistant centre of the fold system must be along the Gulf of Suez, as the steeper wave-fronts are toward it both to eastward and westward. The effects of the folding are greatly exaggerated where granite forms the lowest known member of the fold. In such instances the granite behaves as though it had been a solid wedge driven through the underlying softer strata; the beds near the granitic apex of the anticline are greatly reduced in thickness, and on the steeper side of the arch in extreme cases are pinched out, or otherwise violently dislocated.

The structure in Gebel Zeit is of interest as an example. In the typical cross-section the central axis of the anticline is formed by the granitic massif, on the western flank of which the immediately

[1] *Gebel* means 'hill' in Arabic.

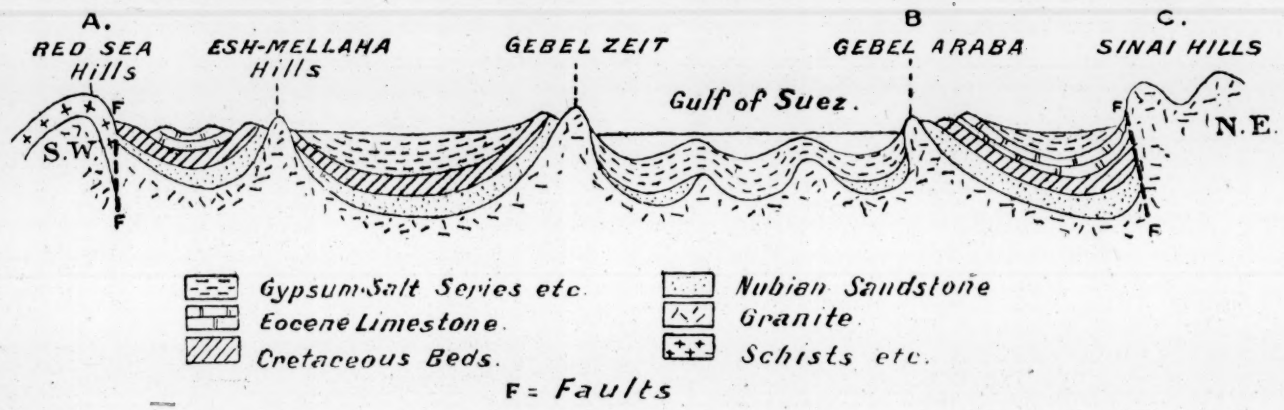

DIAGRAMMATIC SECTION ACROSS THE OILFIELD REGION OF THE GULF OF SUEZ
A.
RED SEA Hills
ESH-MELLAHA Hills
GEBEL ZEIT
B
GEBEL ARABA
C.
SINAI HILLS
Gulf of Suez.
S.W.
N.E.
F
F
F
F
Gypsum-Salt Series etc.
Eocene Limestone.
Cretaceous Beds.
Nubian Sandstone
Granite.
Schists etc.
F = Faults

FIG. 2.

overlying Nubian Sandstone is frequently tilted at high angles (60° or over). The succeeding upper sandstones and Cretaceous strata dip westward from the range at an average of 35°, while the overlying Miocene gypsums and clays have their inclination reduced to 20°. The upper beds of the gypsum only dip 10°, and the Pliocene formations capping the series 4° to 6°. The Nubian Sandstone, which on the west flank is some thousand feet thick, on the eastern flank of the range is reduced to an intensely crushed band, only a few yards in width, immediately overlain by gypsum. It is obvious that the comparative horizontality of Pliocene and Miocene beds at the surface may mask highly disturbed conditions in the strata underneath.

Fuller details are about to be issued on these very interesting questions in a "Report on the Oilfields Region of Egypt" now in the press, where the results of the writer's researches in this region during several years have been summarized. In this connexion I might also call attention to the new volume on the *Geography and Geology of West Central Sinai* by my colleague Dr. John Ball, in which some of the fine faulting along the edges of the Gulf of Suez to the north of the oilfield region is clearly illustrated on Plate xvii.

Through the kind permission of the Director-General I am enabled to send a small map and diagrammatic sketch section of the region specially dealt with, which has become of great economic interest on account of the developments of the petroleum industry in two portions of its area. The occurrence has raised a number of interesting physical and chemical questions, which are now being carefully considered, as a large number of analyses of the deep-seated waters have been made in the Egyptian Government Analytical Laboratory, and the results plotted at the Geological Survey.

III.—*Octotremacis*, its Structure, Affinities, and Age.

By J. W. Gregory, D.Sc., F.R.S., of Glasgow University.

THE Javan fossil corals collected by the Austrian frigate *Novara* included a specimen on which Reuss (1866, p. 172) founded a new genus, *Polysolenia*. He described it (ibid., p. 172) as showing in the structure of its cœnenchyma "eine überraschende Ähnlichkeit mit *Polytremacis* und *Heliopora*". "Das Cönenchym besteht aus langen, ziemlich dicken, geraden, neben einander liegenden Röhren." These tubes, according to his account, occur in circles of six around a central tube. Reuss repeated (p. 174) that the cœnenchyma is composed of regular parallel tubes (Röhren), whereby it is closely allied to *Heliopora* and *Polytremacis*. He named it *Polysolenia* "nach ihrer röhrigen Structur". Reuss' illustrations suggested some suspicion as to the accuracy of his description, since the dark parts of his figures might be interpreted as the original solid structures of the coral, and the light parts as the matrix. If so, the cœnenchyma would be trabecular and the septa a series of thin lamella. Reuss, however, was emphatic that the septa are thicker than the walls of the supposed cœnenchymal canals; and, if so, the light parts of the figure represent the original solid

structures. If the coral had undergone a double change in fossilization Reuss' view was possible; and his statements that the circular rods are casts of canals were so positive that, though in 1900 I mentioned my doubts, I felt bound to dismiss them. So I accepted the fossil as a Miocene Helioporid, and as the name *Polysolenia* was preoccupied renamed the genus *Octotremacis* (1900, p. 302).

A fossil collected by the Right Hon. Sir William Macgregor, G.C.M.G., C.B., etc., from the upper part of the Fly River in New Guinea, shows that my suspicions were justified. This specimen seems to me almost certainly the same species as *Polysolenia hochstetteri*. It agrees very closely with the figures by Reuss, the only noteworthy difference being that the horizontal synapticula are less regularly horizontal than they are there represented. First inspection of the transverse section suggested that in the New Guinea specimen the corallites are considerably larger than in those from Java; but this appearance is due to the section having been cut obliquely. The tubes cut at right angles and the shorter width of those cut obliquely have dimensions very slightly larger than those in *Octotremacis hochstetteri*. In the type of the species the corallites have a diameter of 2 mm., and are from 2½ to 4 mm. apart; whereas in Sir William Macgregor's specimen the diameter is from 2 to 2½ mm. and the corallites are from 2½ to 5 mm. apart. There seems no difference between the corals adequate for their specific separation.

This Fly River coral has, however, clearly a trabecular cœnenchyma, which is composed of parallel vertical rods. Some of the rods project slightly into the tubes of the corallites, and are suddenly reduced in thickness to very thin irregular septa. This specimen shows that the thick vertical structures identified by Reuss as the septa are casts of the interseptal spaces. The septa are the thin intervening lamellæ. According to Reuss their number is eight; but he shows one corallite with seven, and he refers to the occurrence of only six septa. In Sir William Macgregor's specimen the number six is the more common, though specimens with seven and with less than six septa also occur.

As this coral has a trabecular and not a tubular cœnenchyma, its systematic position has to be changed. Instead of being an Heliolitid its affinities are with *Astræopora*. It agrees with that genus in its trabecular cœnenchyma, circular calices, the extreme thinness of the septa, which are absent from some corallites, and the presence of horizontal laminæ, which in vertical sections, as is well shown in Reuss' figure, pl. ii, 3*d*, have almost the aspect of tabulæ. This lamellar structure occurs in many Fungians owing to the development of synapticular platforms. *Octotremacis* may therefore be diagnosed as follows: Madreporidæ with a massive corallum and a loose cœnenchyma composed of vertical trabecula and regular conspicuous horizontal synapticular laminæ. The septa are very thin (but better developed than in *Astræopora*); they vary in number usually from six to eight. No columella. Type, *Octotremacis hochstetteri*, Reuss sp. Eocene, Java.

Whether *Octotremacis* is generically distinct from *Astræopora* is at

present doubtful. The characteristic which offers most evidence for their separation is the development of the horizontal lamellæ. The type species of *Astræopora*, *A. myriophthalma* (Lam.), as figured by Bernard (1896, pl. xxvi), appears to be built of tubular corallites with sharply defined walls, to have no septa visible on the surface, and in vertical section to have no regular synapticular platforms. In *A. listeri*, Bern. (ibid., pl. xxviii), the synapticula are also very irregular, and it has nothing like the regular continuous lamellæ shown in Reuss' figure (1866, pl. ii, fig. 3*b*). Specimens of *Astræopora* in the geological collection of Glasgow University have no synapticular platforms as regular as those in *Octotremacis*. Of the Indian Miocene species, *Astræopora hemispherica*, Dunc., there is unfortunately no information as to the structure of the synapticular platforms; but that species differs from *Octotremacis hochstetteri* by the greater number of septa, for according to Duncan it has six large and about six small septa. According to Bernard, however, in some recent species the horizontal platforms may be so regular "that the whole cœnenchyma appears to be composed of tiers of synapticular floors supported by columns passing through them". He says this structure is very variable and is especially well developed in *Astræopora expansa*, Brügg., and *A. horizontalis*, Bern. In the former he describes the cœnenchyma as consisting of nearly continuous horizontal floors (1896, p. 86).

Thanks to the kindness of F. J. Bell, Esq., I have had the opportunity of examining the types of these two species. *A. expansa* has a flat corallum, shaped like a wide incomplete funnel; at one part of the base a vertical section $\frac{3}{4}$ in. in thickness shows that the horizontal lamellæ are continuous and regular. The type-specimen of *A. horizontalis*, Bern., is a thin sheet, convex above and concave below. Unfortunately the edges are nearly perfect, so that they do not show the internal structure, and the fractures on the under surface do not give any clear evidence as to the nature of the horizontal lamellæ. As the type is the only specimen, it is thought unjustifiable to cut it in order to determine its structure.

If Bernard's view be correct, the horizontal lamellæ are of no diagnostic value, as they depend largely on the shape of the corallum, in flat coralla the vertical element being reduced and the horizontal platforms being well developed. The spreading growth of some coralla may, however, be the result rather than the cause of the predominance of the horizontal element. It does not seem possible to decide as to the value of this character until the internal structure of the recent species is better known. The most convenient course at present is therefore to retain *Octotremacis* provisionally as a sub-genus of *Astræopora* characterized mainly by the regular development of its synapticular platform.

Age.—*Octotremacis* was identified as Miocene because the other corals from Java described by Reuss were of that age. The type of this genus was, however, found under different conditions from the rest of the collection. It was a fragment collected from a trachyte breccia at Tjukang-Raon, and there is no direct evidence from Java as to its age. It may have been introduced into Miocene tuffs

from an underlying platform of older rocks. The specimen from New Guinea was found with a series of corals and Foraminifera which indicate that it is Eocene and probably Middle Eocene (Gregory and Trench, 1916, p. 532). The type-specimen from Java is probably of the same age.

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IV.—On the Geology of the District from Cil-y-Coed to the St. Annes–Llanllyfni Ridge (Carnarvonshire).

By E. WYNNE HUGHES, M.Sc., F.G.S.

(PLATES I and II and two Text Maps.)

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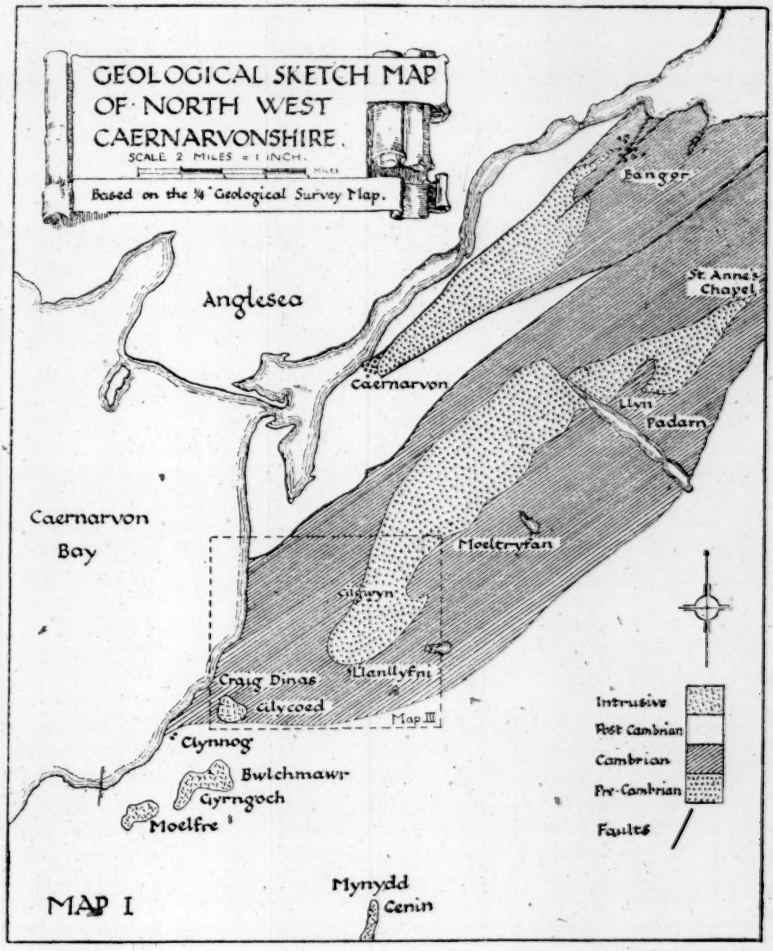
I. Introduction. (See Map I in text.)

THE existence of two ridges of Pre-Cambrian rocks in South-West Carnarvonshire is well known. The more northerly of these ridges extends from near Bangor to Carnarvon, a distance of just over 8 miles. It runs in a south-westerly direction, close to and parallel with the Menai Straits, and terminates at the hill called Twthill—a prominent feature in the town of Carnarvon. The more southerly

ridge—commonly known as the St. Annes–Llanllyfni ridge—stretches from St. Annes in the Nant-Ffrancon Valley to the village of Llanllyfni in the Nantlle Valley. This ridge is 12 miles long and has a south-westerly trend; it is therefore roughly parallel to the Carnarvon–Bangor ridge, from which it is distant about 2 miles. It is with the area at the south-west end of the St. Annes–Llanllyfni ridge that the following remarks are concerned. The object of my



MAP I

investigation has been to establish the succession of rocks in this area, and to correlate it, if possible, with the main portion of the ridge lying to the north-east. The results are set out in detail in the following pages. Text-map I shows the position of these two Pre-Cambrian ridges and also the extent of the area to be considered in detail.

II. Previous Literature.

Concerning the geology of these two ridges, the controversy as to the age of the rocks and their relation to the neighbouring formations has produced a voluminous literature. It is unnecessary to dwell in great detail upon this literature, and only the main conclusions, in as far as they appear to affect the area to be described, need be considered here.

1. General.

In 1866 the Geological Survey memoir of North Wales was published. From this it is seen that Ramsay maintained that the base of the Cambrian system in Carnarvonshire is not seen.[1] He further considered that the Cambrian Slates and Grits pass downwards into a conglomerate which in turn passes by insensible gradations into a quartz-porphyry which forms the core of the St. Annes–Llanllyfni ridge.[2] This gradual transition of the conglomerate into a quartz-porphyry was explained as a metamorphic change brought about by pressure, and the quartz-porphyry itself was supposed to be the extreme stage of the transition.[3]

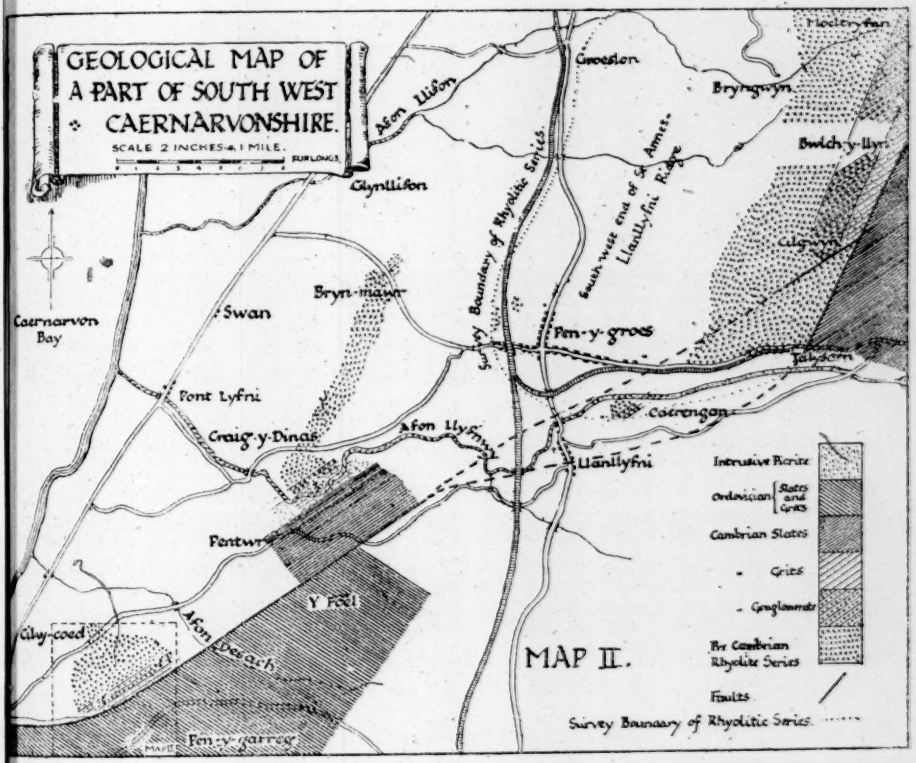
This somewhat interesting interpretation of the relation between the conglomerate and the quartz-porphyry resulted in an examination of the area by several geologists, amongst whose number were Blake, Bonney, Hicks, and McKenny Hughes, and at a later period Tawney and Geikie. All agreed that the theory of the metamorphic origin of the quartz-porphyry was erroneous, and that in reality the mass was composed of an original igneous rock. There was, however, considerable divergence of opinion as to whether the rocks were of intrusive or extrusive character. Hicks,[4] McKenny Hughes,[5] and Bonney[6] considered that this so-called quartz-porphyry was an eruptive mass composed of lavas, tuffs, and breccias, showing in places both fluxion and spherulitic structures. Tawney maintained that these rocks were intrusive.[7] Blake also at first maintained that they were intrusive, but later he modified this view and admitted the possibility that they were contemporaneous lava-flows.[8]

A further controversy arose as to the significance of the conglomerate lying upon this igneous series. It was demonstrated by Hicks,[9] McKenny Hughes,[10] and Bonney[11] that the pebbles in the conglomerate were mainly composed of fragments from the underlying volcanic rocks, and accordingly they concluded that a geological break existed here, and that the conglomerate marked the base of the Cambrian system in Carnarvonshire. The series was thus implied to be of Pre-Cambrian age. On the other hand, Tawney[12]

[1] A. C. Ramsay, *Geology of North Wales* (Mem. Geol. Surv.), vol. iii, p. 2, 1866.
[2] Op. cit., p. 142.
[3] Op. cit., p. 140.
[4] Q.J.G.S., vol. xxxiv, p. 132, 1878.
[5] Q.J.G.S., vol. xxxiv, p. 142, 1878.
[6] Q.J.G.S., vol. xxxv, p. 310, 1879.
[7] Geol. Mag., Vol. IX, p. 552, 1882.
[8] Q.J.G.S., vol. xliv, p. 282, 1888.
[9] Q.J.G.S., vol. xxxiv, p. 148, 1878.
[10] Q.J.G.S., vol. xxxiv, p. 142, 1878.
[11] Q.J.G.S., vol.xxxv, p. 311, 1879.
[12] Geol. Mag., Vol. X, p. 70, 1883.

and Geikie[1] maintained that the conglomerate merely marked a phase in the Cambrian succession, and agreed with Ramsay that the base of the Cambrian succession was not exposed in Carnarvonshire. Blake also had previously maintained this latter view,[2] but at a later date he went so far as to suggest that the Moel Tryfan conglomerate—lying directly on the volcanic series—was of post-Cambrian age.[3]

The view generally held nowadays is that although no unconformity has been shown to exist anywhere along the ridge, yet the volcanic series is Pre-Cambrian and the conglomerate is basal Cambrian.



2. Particular Area, including Cil-y-Coed, Craig-y-Dinas, and Bryn-mawr. (See Map II.)

Turning now to the literature relating to the district immediately south-west of the main ridge, one finds that very little attention has been paid to the ground. The Survey memoir of 1866 only refers to

[1] *Ancient Volcanoes of Great Britain*, vol. i, pp. 160, 163, 1897.
[2] Q.J.G.S., vol. xliv, p. 288, 1888.
[3] Geol. Assoc. Report of Blake's Caernarvonshire Excursion.

the area in a very general way. The village of Llanllyfni is mentioned as the most southerly extremity of the quartz-porphyry of the St. Annes–Llanllyfni ridge,[1] and the conglomerate is said to extend in this south-westerly direction no further than Mynydd Cilgwyn.[2] The exposures at Bryn-mawr, Cil-y-Coed, and Craig-y-Dinas are not referred to at all by name; but in the 1 in. Geological Survey map published in 1850 the area containing Bryn-mawr and Craig-y-Dinas is designated as *b'*—Lower Cambrian—and Cil-y-Coed is mapped as an intrusive felspathic rock. Hicks in a map accompanying his paper on the Pre-Cambrian rocks of Carnarvonshire indicated that he considered the rocks of Cil-y-Coed, as also of Pen-y-gaer, Tre-Ceiri, Yr Eifl, Gryn-ddu, Gryn Goch, Bwlch Mawr, and Mynydd Cenin, to be of Pre-Cambrian age.[3] The igneous rocks at all those localities, however, have been claimed by Harker as of Ordovician age.[4] Again, in a further paper, Hicks claimed that the rocks at Craig-y-Dinas were of Pre-Cambrian age,[5] and with regard to Cil-y-Coed he writes as follows:—

"In the absence of true Lower Cambrian rocks in this area, the evidence of their age has to be frequently based on the general character of the rocks themselves and the behaviour of the beds in contact with them . . . The small mass to the north of Clynogg Fawr (presumably Cil-y-Coed or Pen-y-garreg) is of the same character as the above-mentioned masses—a quartz-porphyry—and is also surrounded by Upper Cambrian rocks, and on one side by even Lower Cambrian beds also unaltered in contact."[6]

Tawney also visited this district, and in his paper on "The Rocks of Caernarvonshire", after a general discussion of the rock exposures in the county, he remarks:—

"It seems to me that there is sufficient evidence that these are igneous rocks intruded through Cambrian shales in the manner delineated in the Geological Survey Map. To begin with, the mass about 1 mile north-east of Clynnog, at Cil-y-Coed, is a quartz-porphyry of pinkish grey colour."[7]

Harker, in his Sedgwick Essay on "The Bala Volcanic Series of Carnarvonshire", refers to the mass at Cil-y-Coed in the following words:—

"Proceeding south-westerly we come to Clynnog district, where a number of distinct intrusions occur, which unfortunately have not all been studied in detail. There is a chain of four large hills due to four sets of connected intrusions. The other intrusions in the neighbourhood are quartz-porphyries of various characters, the Pen-y-gaer rock being a beautiful granophyre, while the little bosses of Cil-y-Coed, north-east of Clynnog-fawr and Moelfre near Llanhaelhaiarn, show Rhyolitic affinities."[8]

III. Exposures.

The country for some distance to the south-west of the St. Annes–Llanllyfni ridge is comparatively flat and low-lying. It is mainly

[1] Mem. Geol. Surv., 1886, p. 140.
[2] Op. cit., p. 143.
[3] Q.J.G.S., vol. xxxv, p. 297, 1879.
[4] Harker's *Bala Volcanic Series of Carnarvonshire*, 1888, p. 44.
[5] Q.J.G.S., vol. xxxv, p. 296, 1879.
[6] Op. cit., p. 298.
[7] Geol. Mag., Vol. IX, p. 552, 1882.
[8] *Bala Volcanic Series of Carnarvonshire*, 1888, pp. 44–5.

drift-covered, and in consequence well cultivated. As a result only three rock-exposures occur in this area—Cil-y-Coed, Craig-y-Dinas, and Caer Engan. Cil-y-Coed and Caer Engan are two small hills, whilst Craig-y-Dinas, with Pentwr to one side of it and Brynmawr to the other, are on the slopes of rising ground. It will be convenient to consider each of these exposures separately, commencing with Cil-y-Coed, which is the largest and also the most south-westerly of the three.

1. Cil-y-Coed. (See Map II.[1])

A. Surface Features.—This hill, situated about three-quarters of a mile from the village of Clynnog Fawr on the north-west coast of Carnarvonshire, attains an elevation of about 480 feet O.D., and stands out prominently from the drift plain which stretches for 6 or 7 miles along Carnarvon Bay. It is the first hill of a series increasing progressively in height towards the south, and it covers an area of nearly a quarter of a square mile, being about 1,000 yards long and 900 yards wide at its broadest part. The northern slopes of the hill are everywhere gentle, except at the extreme north-west, where crags are exposed, making the slope somewhat steeper. On the south-west and west sides, however, the ground drops very abruptly from 480 to 200 feet, below which level there is a gentle slope down into the plain. On the north side the rocks are smoothed by glaciation, and the lower flanks of the hill on every side are covered with a thin deposit of drift. The contour of the hill was undoubtedly carved out by the Irish Sea ice-sheet, which traversed the hill from the north. There is also a small capping of drift on the actual summit near the south-west extremity.

B. Pre-Cambrian, the Rhyolitic Series.—The hill in part undoubtedly owes its prominence to an igneous rock which is exposed more or less continuously in a line of crags on the west side extending from the roadway to the top of the hill, a distance of about 650 yards.

(i) *Stratigraphy* (see Map II).—It will be convenient to begin our description with the most northerly rocks exposed. These are to be seen on the north-west side of the hill, 20 yards away from the small quarry that is situated here. In hand specimens the rock appears to be a dark felsite, noticeable for the presence of numerous porphyritic crystals of quartz and of pink felspar. The groundmass is fine-grained and compact, hence the rock is very hard and tough.

The next exposure examined is in the quarry itself, where the rocks appear in hand specimens to be rather different from those just described. Although still felsitic-looking the rocks here are light-coloured, and only on close examination are any porphyritic crystals to be seen. In the mass the rock appears to be a rhyolite, and it is probably to the rock exposed in this quarry that Tawney and Harker refer. The rocks are much jointed and sheared, and readily break into angular chips. The main joints strike E. 10° N. and dip N. 10° W. at an angle varying from 60° to 80°. Other joints strike

[1] The area here dealt with is shown on Map II in dotted lines.

N. 40° E. and dip N. 50° W. at an angle of 60°, being thus roughly at right angles to the major joints.

In traversing the hill in a south-easterly direction from the quarry several rock exposures are met with. A few yards away from the quarry a dark rock, containing porphyritic crystals of quartz and pink felspar, is seen once more. It is in every respect macroscopically similar to the dark felsitic rock mentioned above. We thus have a band of pale felsitic rock (which we may term the pale variety) lying between two dark felsitic bands (which we may term the dark variety). The more southerly band is about 40 feet wide. Following is a narrow band of the pale variety. Succeeding this a dark felsitic rock again occurs as a band about 20 feet wide. Macroscopically it only differs from the dark bands in that the pink felspars are distinctly smaller. This band is succeeded by another of the pale variety—15 feet thick—and in turn by a massive dark band, macroscopically very similar.

Proceeding eastwards from this point, there is no exposure for fully 100 yards until another small quarry is reached. From here on to the most easterly part of the hill, igneous rock is exposed at several places, but in all cases it consists of the pale variety, macroscopically similar to bands already noticed in the first quarry.

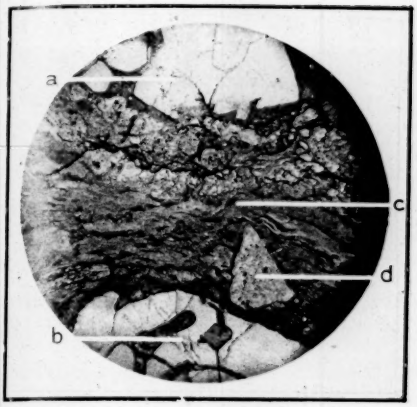
Along the south-west flanks of the hill a similar alternation of the pale and dark rocks is evident. These bands, however, are not persistent. For instance, the thin band does not occur on this side, so that two bands have here coalesced, giving a massive band of the dark variety having a width of fully 100 feet. Further south occurs also a tongue of the dark variety wedging into the pale variety. The line of strike given by this rough banding of the two varieties of rock is N. 60° E.

(ii) *Microscopic Description.*—On examining thin sections of the rock from the various exposures there is found to be a surprising resemblance between the pale and the dark varieties.

(*a*) Phenocrysts.—In both cases porphyritic quartz and felspar crystals are prominent, the quartz being the more abundant. The quartz sometimes show good crystal forms, but more often are corroded and rounded (Pl. I, Figs. 1, 2), and frequently the matrix may be seen in cracks in the crystals (Pl. I, Figs. 1 and 5). Most of the porphyritic crystals of felspar are plagioclases with multiple twinning (Pl. I, Fig. 5), but in nearly all cases simply twinned or untwinned crystals of orthoclase are also present (Pl. I, Fig. 1). The plagioclases appear to approximate to albite, and crystals of chequer albite[1] are occasionally present. This chequer albite is sometimes intergrown in perthitic fashion with untwinned felspar. Phenocrysts of biotite are also sparingly distributed throughout the rock. Muscovite, evidently of secondary origin, is always present.

(*b*) Groundmass.—These various phenocrysts are embedded in a felsitic groundmass. This again shows a general similarity in both the pale and the dark varieties, although a certain amount of

[1] J. S. Flett, Mem. Geol. Surv. (Newton Abbot), 1913, p. 60.



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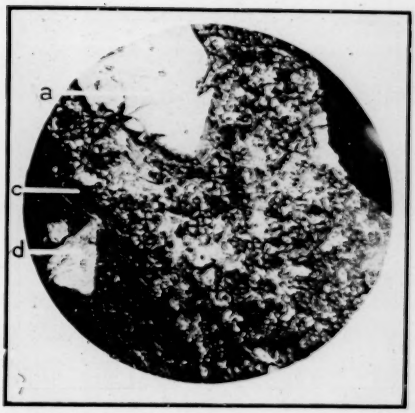

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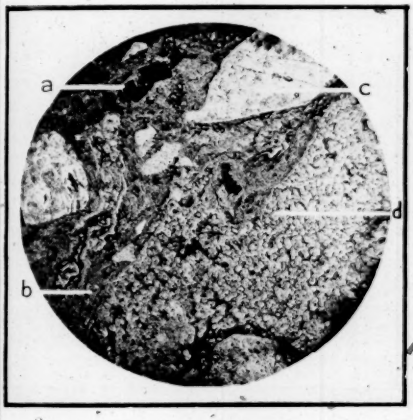

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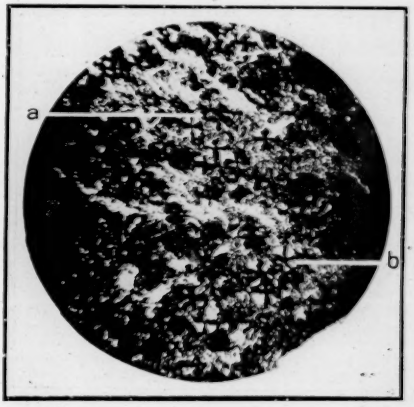

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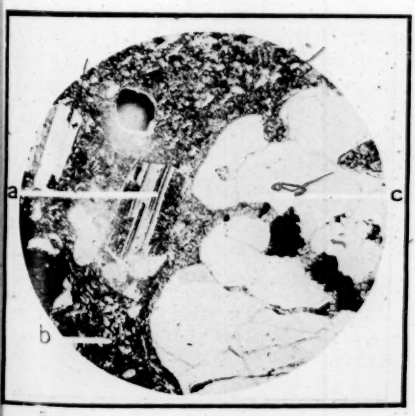

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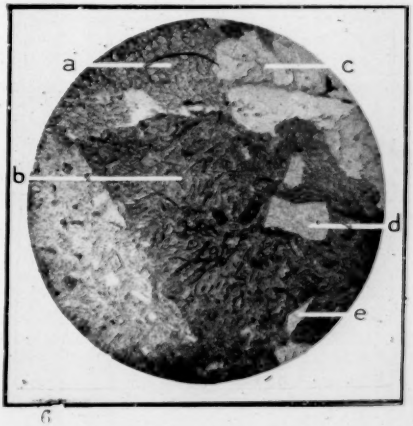


6

ROCK-SECTIONS, CIL-Y-COED.

variation is usually to be seen even in a single rock section. The matrix is typically cryptocrystalline, but occasionally becomes microcrystalline in character. Microspherulitic textures are of frequent occurrence, and on the whole this is more commonly the case in the dark variety.

In many cases the manner in which the various types of matrix are intermingled one with another and drawn out in streaky fashion shows that we are dealing with rhyolites having a well-defined flow-structure. This structure is sometimes developed on a very small scale (Pl. I, Figs. 1, 3). In other cases, however, the original character of the rock is by no means so clear, since in these the matrix with its different types of recrystallization presents a patchy rather than a streaky texture, suggesting at first sight a tuff. The streaky appearance, however, still persists to a certain extent, and in such cases the patches frequently end off rather abruptly along the direction of the flow-structure. It is extremely difficult to determine whether such rocks are lavas with flow brecciation or rhyolitic tuffs containing rhyolitic lapilli.

The presence of the very numerous and large felspar phenocrysts and still more so of the quartz phenocrysts immediately suggests that the rocks belong to a series of Pre-Cambrian age, since these characters appear to be of universal occurrence in the Pre-Cambrian rhyolites of Wales, whereas they are not found in the Ordovician rhyolites. In this connexion it is also noteworthy that the microspherulitic texture described above appears to be of frequent occurrence in the Pre-Cambrian rhyolites of North Wales, whereas it is not found to any extent in rhyolites of Ordovician age in North Wales.

C. Cambrian Sedimentary Series. (i) *Conglomerate.* (*a*) Stratigraphy.—Beyond the rhyolite we come to the crags which form the highest ridge on the hill at its south-west end. These crags are due to the presence of a hard conglomerate, the nature of which is well shown on the weathered surfaces. The well-rounded pebbles in this conglomerate vary considerably in size; whilst the majority are from 1 to 2 inches in diameter, others may attain a diameter of 12 inches. These pebbles are embedded in a fine gritty matrix. All the pebbles consist of felsites with porphyritic crystals of quartz and felspar, and they closely resemble the rocks of the rhyolitic series already described. In fact, near the line of junction of the conglomerate and the rhyolitic series, where the pebbles of the conglomerate have been pressed into the rhyolitic rock, the resemblance between the two is so close that it is only on careful examination that the outline of the pebbles can be seen.

This conglomerate strikes N. 80° E. When followed across the strike in a south-westerly direction the conglomerate passes into a grit which is, however, still occasionally pebbly. This conglomerate band continues until it is buried in the drift on the south-west slopes of the hill.

Proceeding along the strike in the opposite direction—north-east—the pebbles decrease rapidly in size in the course of a few yards, but the matrix retains its original character. In a newly opened quarry

at the north-east end of the hill, quite a number of pebbles of rhyolite, some 3 to 4 inches long, are seen, but the majority of the pebbles are small and well rounded. It is only in this exposure that we get any indication of stratification in the conglomerate. Generally the dip of the rock is quite obscure, as is often the case in massive conglomerates; but in the freshly cut rock in this quarry alternate layers of pebbles and fine grit are distinctly visible. The lie of the pebbles suggests a dip of about 50° to S.E. In the quarry the rock is seen to be jointed, some joints sloping in the direction of the dip of the pebbles, crossed by others at right angles.

(*b*) Microscopic Examination.—Several thin sections were prepared from specimens collected from different places along the outcrop, both from the highly pebbly conglomeratic portion and from the less pebbly and more gritty portion. Every slide confirms the conglomeratic nature of the rock. They show the presence of felspar, quartz, and numerous chips of rhyolite and fragments of tuff (Pl. I, Fig. 6; Pl. II, Fig. 1). The felspars usually exhibit multiple twinning, but are mostly decomposed. The quartz almost invariably show subangular edges. The matrix is felspathic and fine-grained, often containing small crystals of muscovite.

Sections of some of the larger pebbles were also examined, and these compare in every respect with the rhyolitic rocks described above (p. 19). They contain crystals of felspar and quartz embedded in a felsitic groundmass, which in some cases shows a characteristic flow-structure.

At right angles to the strike—in a south-east direction—the conglomerate rapidly changes to a grit, the width of a distinctive conglomerate being about 18 feet.

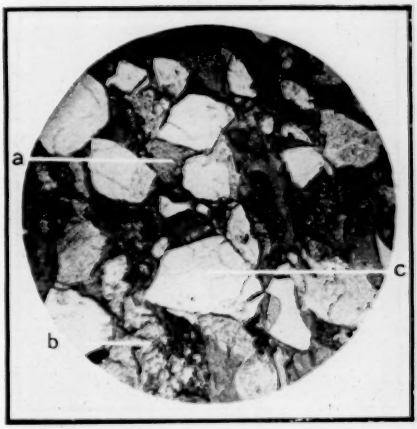
(ii) *The Grit Band.*—(*a*) This band of grit is about 12 feet thick, and extends from the south-west to the north-east end of the hill. Under the microscope the grit is seen to contain angular and subangular crystals of quartz in large number, along with numerous felspar crystals (partly kaolinized); and occasional chips of rhyolite also occur (Pl. II, Fig. 1).

(*b*) This fine grit, when followed southwards across the strike, gives place to a distinctly coarser rock which is very much weathered. When followed along the strike to the south-west this rock becomes still coarser and still more weathered. A microscopic examination shows the rock to be largely composed of angular quartz crystals—often sheared—set in a felspathic cement (Pl. II, Fig. 5).

Both these bands of grit, fine and coarse, persist in a north-easterly direction for a distance of 900 yards, with but a slight break where the hill is capped with drift. At the north-east end of the hill there is the same succession of conglomerate, fine grit and coarse grit, precisely as one would expect to find them on the supposition that the dip is, as stated above, S. 30° E.

There is a decided dip in the ground beyond the outcrop of the quartz grit, and no further exposure is visible, all the land on the south-east side of the grit being under cultivation. This is most unfortunate, as it is impossible without further exposures on that side to determine the exact relation of the grits to the other formations of the district.

1



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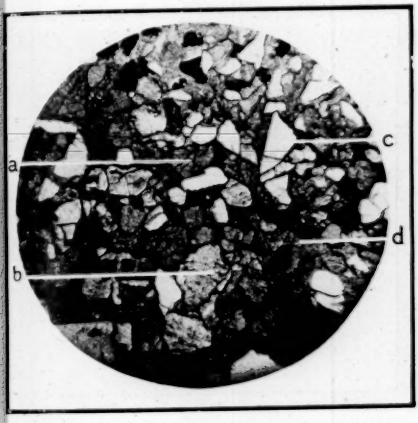

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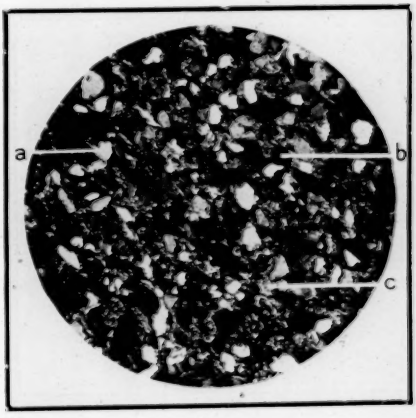

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5

6

ROCK-SECTIONS, CIL-Y-COED; AND 4 AND 6 BWLCH-Y-LLYN.

D. Summary of the Succession.—We have then at Cil-y-Coed the following descending sequence:—

(i) A quartz grit 6 or more feet thick.
(ii) A fine felspathic grit 8 feet thick.
(iii) A conglomerate 18 feet thick.

All with a strike N. 60° E. and a dip of 50° to S. 30° E. These rocks rest on

(iv) A volcanic series consisting of rhyolitic lavas and tuffs which appear to dip 60–80° N. 10° W.

The pebbles in the conglomerate are undoubtedly derived from the underlying rhyolitic series.

This apparent discordance of dip suggests the presence of an unconformity between the sedimentary rocks and the volcanic series of rocks. The exposures, however, are not sufficient to actually prove the existence of this unconformity, and it would require considerable trenching to make it apparent.

E. Relation to the Surrounding Areas.—On attempting to trace the beds into surrounding areas we find that Cil-y-Coed is somewhat isolated.

(i) *North and West Side.*—On the north and west side the mass is flanked by glacial drift, which stretches as a continuous sheet right to the seashore, 500 yards distant.

(ii) *South-East and East Side.*—On the south-east and east side the ground is under cultivation, and no semblance of solid rock is to be seen except in a field near Garregboeth, distant 30 yards from the nearest exposure of the grits. Here an arenaceous slate is seen, but it is doubtful whether this rock is really in situ. Assuming that it really is in place, then it undoubtedly forms a continuation of a considerable mass of arenaceous slate which is exposed at Pen-y-garreg some yards further on. Between these two exposures there is an intrusive mass of picrite.

This band of arenaceous slate gives rise to a prominent feature at Pen-y-garreg, and it can be traced for at least two miles to the south-west, the outcrop generally running in a north-east to south-west direction.

In the Survey memoir this arenaceous slate is considered to be of Silurian (Ordovician) age, but no fossils have as yet been found in the neighbourhood. The slate is very different from the blue and purple slates of the Cambrian Series, which are so persistent in the Nantlle Valley and were traced by the Survey as far as Llwyd-Coed, three miles north-east of Cil-y-Coed. The Survey assume the existence of a fault in this neighbourhood throwing down the Silurian beds against Cambrian rocks. The memoir states:—

"South of Llanllyfni the strike of the Cambrian rocks changes to east and west, and the purple slate does not occur south or south-west of Mynydd Llanllyfni and Ty Coch near Clynnog Fawr. The drift-covered district further south is composed of black and ferruginous Silurian shales and grey sandstones. The point farthest south where purple slate has been found is at Llwyd-Coed about a mile south of Llanllyfni, and to the west of the last-named place the ground is so obscure that the reason for the disappearance of the slate is unknown. The fault which throws the (Cambrian) slate against the quartz porphyry ridge (St. Annes–Llanllyfni ridge) is probably continued along

the boundary of the trap as far as Llanllyfni, and west of that village perhaps throws the slate down against the low Cambrian grits and conglomerates that form the western boundary of the porphyry."[1]

If we accept these slates on the south-east side of Cil-y-Coed as Ordovician, as the Survey imply, the only inference that can be drawn is that the Cil-y-Coed Series is of earlier date than Lower Ordovician.

(iii) *South-West Side.*—On the south-west side the rock surface slopes steeply until cultivated land is reached. This is the case all along this side except at the extreme end of the mass. Here the rock disappears in a wooded glen, and although the glen is narrow and deep, with a brook running down its entire length, no exposure is seen anywhere in the glen; but the debris in the bed of the brook suggests the proximity of the rhyolitic series. On the south side of this brook and 30 yards from it is an old "trial" level. This adit cuts into slate. The slate is black and is irregularly cleaved, the cleavage striking E. 10° N. and dipping 80° S. 10° E. In this adit there are about five hard black bands varying from 1½ inches to 2 feet in thickness and dipping in the same direction as the cleavage, but at a slightly smaller angle. The black bands are not cleaved, but are somewhat stratified parallel to their edges. They undoubtedly mark the true dip of the beds, which is therefore about 60° to the south. The slate in the adit is undoubtedly identical with the black ferruginous slate of the Ordovician system. It is in the direct line of strike of the grits on Cil-y-Coed.

The difference in the dip, but the much greater difference in the nature of the exposures on each side of the brook, coupled with the narrow glen separating the two, suggests the presence of a fault at this point. The map accompanying the Survey memoir shows a fault between the Cambrian and the Silurian Series curving round to the west at a point about 100 yards to the north-east of Cil-y-Coed. This fault has already been referred to (p. 21) in the extract from the Geological Survey memoir. A continuation of this fault in its south-westerly direction for another 1,200 yards, before turning to the west, would bring it down the glen separating the Cambrian and Pre-Cambrian rocks from these Ordovician slates in the quarry. Such a prolongation of the fault is shown in Maps I and II.

(iv) *North-East Side.*—Following the strike of the Cil-y-Coed rocks in a north-easterly direction we come again to cultivated land, where no rock exposure is visible. A careful search in all the fields on this side of the hill discloses no rock exposures. The River Desach cuts its way through a gap on this side, but even here no rock exposures are found. A little way on, however, at Pentwr, half a mile from the most easterly exposure on Cil-y-Coed, a small quarry was opened in 1912 for building-stone. The rock here exposed is a bluish fine-grained grit, approximating almost to a hard shale. At the south-west end of the quarry is green slate, but no indication of the dip is disclosed in this exposure. Further to the east, 60 to 70 yards away, there is again an exposure of green slate; the weathered surface shows the cleavage to strike E.N.E.–W.S.W.,

[1] Mem. Geol. Surv., 1866, p. 143.

but the dip of the beds is not clear in such a small exposure. Continuing from here in a N.N.E. direction we come to a much larger exposure of rocks at Craig-y-Dinas, separated from Pentwr by three small exposures of purple slate. The several exposures in this neighbourhood will now be described in greater detail.

2. Pentwr, Craig-y-Dinas, and Bryn-mawr.

These three places are on the slopes of a ridge which stretches practically from Glynllifon to Cil-y-Coed. The crest of this ridge along almost its whole length attains an altitude of 200 feet. At Craig-y-Dinas the River Llyfnwy cuts through the ridge in a roughly semicircular sweep exposing precipitous rocks at several localities on both banks of the river.

A. Cambrian, Sedimentary Rocks. (i) *Conglomerate.*—This rock is best exposed on the right bank of the river at the end of the gap farthest from the sea. The pebbles in this conglomerate are comparable in size with those at the north-east end of the exposures at Cil-y-Coed, being seldom more than an inch in length. They consist essentially of rhyolitic and felsitic chips. In addition occasional chips of a slaty nature occur, and in this respect the rock differs from the Cil-y-Coed conglomerate. The matrix of the conglomerate is felspathic, and approximates both in hand specimens and under the microscope to that already described at Cil-y-Coed. The rock is considerably sheared, and the pebbles have arranged themselves in the direction of shear, which dips generally at an angle of 70° S.S.E. The true dip of the conglomerate is obscured by cleavage.

(ii) *Grit.*—Overlooking the conglomerate, to the south-east of it, is a coarse grit in which there are several bands of a much finer grit. Some of these bands, though only 1 inch thick, are very persistent. In one locality the river runs for 100 yards in a N.E.–S.W. direction. Here the bands are perfectly horizontal, suggesting that the strike of the rock is approximately in the same line. Further down the river runs east and west, and here the dip of the beds can be observed owing to the alternation of fine and coarse bands. A lateral gap, at another locality further east, shows that the banding is persistent on both sides of the gap. The dip given by this banding is 50° S.E.

At the extreme southerly bend of the river the grit becomes much less felspathic, approximating more nearly to a quartzite. The rock weathers almost white, and on breaking shows crystals of opalescent quartz. This type of rock is predominant on the south-east bank of the river. Near the farm of Pen-y-bont (also on the left-hand side of the river) there is another exposure of quartz grit. It forms a small island bounded on one side by the river and on the other side by a "cut out" or old overflow channel. The line of outcrop here trends 20 N. of E., and the beds are very nearly vertical. This does not agree with the observations in the main mass.

(iii) *Purple Slate.*—For some distance beyond this grit the land is completely under cultivation and no exposures are visible. However, in a well that was dug in 1913 in the school playground at Bryn-eurau (500 yards south-west of Craig-y-Dinas) purple slate was

reached. Exposures of purple slate also occur in the meadow below Coch-y-big, and also near the outhouses at Llech-y-dwr.

The dip of the slate cannot be ascertained, but the position of the three exposures gives some indication that the strike here is similar to that of the Cambrian slates in the Nantlle Valley—namely N.N.E.–S.S.W. If this were the case, purple slates would be present at a point within 300 yards of the grits at Craig-y-Dinas, in the exact position in which they should stratigraphically occur. Unfortunately the exposures are not sufficient to verify this. The Survey memoir mentions Llwyd-coed (2 miles to the north-east) as the most southerly exposure of the Cambrian purple slates.[1]

(iv) *Green Slate.*—One hundred yards due east of the exposure of purple slate at Llech-y-dwr the one already referred to at Pentwr is found. This exposure shows a band of fine grit in green slate, both macroscopically very similar to the grits and green slate that overlie the purple slate both in the Nantlle and Llanberis quarries. Still further east, 60 to 70 yards away, near Ysgubor-Wen, there is also an exposure of green slate. As already mentioned, the weathered surface shows the cleavage to strike E.N.E.–W.S.W., but the dip of the beds cannot be determined in such a small exposure.

No further exposures of any description are to be seen in this neighbourhood until we come to the hill of Y Foel. The whole of this hill consists of black slate showing poor cleavage and containing iron pyrites in large quantity. These slates are put down as of Ordovician age in the Geological Survey map, but no fossils have been obtained here. They closely resemble the black slates in the quarry to the south-west of Cil-y-Coed.

EXPLANATION OF PLATES.

Plate I.

Fig. 1.—Quartz-rhyolite, Cil-y-Coed. Showing two large crystals of corroded quartz (*a*) and (*b*); fluxion structure (*c*) winding round a crystal of muscovite on the left and of orthoclase (*d*) on the right. Natural light. × 18.

,, 2.—(Fig. 1 above, under crossed nicols.) Showing microspherulitic structure. The quartz crystal (*a*) and the orthoclase crystal (*d*) are the same as in Fig. 1. The flow-structure (*c*) is still evident. × 18.

,, 3.—Rhyolite, Cil-y-Coed. Showing very small spherulites (*d*) and fluxion structures (*b*); also porphyritic crystals of biotite (*a*) and orthoclase (*c*). Natural light. × 18.

,, 4.—(Fig. 3 under crossed nicols.) Showing microspherulitic structure (*a*) and (*b*). × 80.

,, 5.—Rhyolite, Cil-y-Coed. Showing slight flow-structure (*b*); phenocrysts of plagioclase (*a*) and quartz (*c*), corroded and invaded by the groundmass. Crossed nicols. × 18.

,, 6.—Conglomerate, Cil-y-Coed. Showing a chip of felsite (*a*); quartz (*d*); and an angular chip of tuff (*b*) containing a quartz crystal (*c*) and a decomposed felspar (*e*). Natural light. × 18.

Plate II.

,, 1.—Matrix of conglomerate, Cil-y-Coed. Containing subangular quartz crystals (*a*) and grains of felsite (*b*) and (*d*) in an abundant sericitic matrix (*c*). Natural light. × 18.

[1] See extract on p. 21.

FIG. 2.—Matrix of conglomerate, Cilgwyn. Containing subangular quartz crystals (*c*) and grains of felsite (*a*) in an abundant sericitic matrix (*b*). Natural light. × 18.

,, 3.—Quartz grit, Cil-y-Coed. Containing angular quartz crystals (*c*) embedded in a felspathic groundmass; small grains of felsite (rather decomposed) (*a*); occasional felspars (*b*); and abundant iron-ore (*d*). Natural light. × 18.

,, 4.—Quartz grit, Bwlch-y-llyn. Containing angular quartz crystals (*a*) embedded in an abundant matrix (*c*) now largely decomposed into sericite. Abundant iron-ore (*b*). Crossed nicols. × 18.

,, 5.—Sheared quartzite, Cil-y-Coed. Crossed nicols. × 18.

,, 6.—Sheared quartzite, Bwlch-y-llyn. Crossed nicols. × 18.

(*To be concluded in our next Number.*)

V.—Dr. Charles D. Walcott's Cambrian Geology and Palæontology.[1]

By V. C. Illing, F.G.S.

TO the student of Cambrian geology, the writings of C. D. Walcott are always matters of enlightening study, not only for the matter they contain but also because they combine that admixture of stratigraphy and palæontology in which the latter, though accorded a prominent position, is always used to the full to subserve the wider claims of the former.

In a consideration of the series of papers on Cambrian Geology and Palæontology in the Smithsonian Miscellaneous Collections, the subjects covered are so varied and extensive that only a few of the more salient points can be considered. Perhaps it will be most convenient to discuss the material under the two general considerations of the more purely palæontological and the stratigraphical.

Among a series of new forms, some of the most remarkable are a number of Merostomata, Malacostraca, Holothuroidea, and Annelids, found in the Burgess shale of the Stephen Formation in British Columbia. In many cases the impressions of the organic structures are beautifully preserved in the fine-grained material, a fact to which full justice is done in the figures. The Merostomata are particularly interesting in this connexion as indicating to what a degree of development these Middle Cambrian faunas had attained. But to the stratigrapher it is the trilobites to which the main interest generally attaches, and among the various groups the Mesonacidæ or Olenellidæ stand out in their interest and importance. This family, characterized by its large head, large crescentic eyes, rudimentary facial sutures, genal spines, and long and variable thorax, has now been divided into a number of genera based mainly on variations in the thorax. Walcott recognizes six main stages in the development in an order of decreasing number of thoracic segments.

1. Nevadia Stage. The seventeen anterior thoracic segments are of the usual type, but are followed by eleven primitive posterior segments with spinous extensions.

2. Mesonacis Stage. The first fifteen segments are normal, except the third, which is enlarged, and the fifteenth, which has a median spine. The ten posterior segments are normal in shape but small.

[1] Smithsonian Miscellaneous Collections, 1910–15.

3. Elliptocephala Stage. The first fourteen segments are of the uniform type, while the posterior five segments are short and have long median spines.

4. Holmia Stage. The sixteen segments of the thorax are all of the uniform type.

5. Pædeumias Stage. The third segment is enlarged and the fifteenth segment is developed into a long spine. Beneath and behind this spine there are from two to six similar but smaller spines.

6. Olenellus Stage. There are only fourteen segments, of which the third is enlarged; the fifteenth segment has developed into a strong telson.

These changes in the thorax are sufficiently marked to form good generic delimitations in most families of trilobites, but it seems possible that the Mesonacidæ were undergoing rapid evolution; thus *Olenellus thompsoni* goes through a Holmia and Pædeumias stage before reaching the true Olenellus stage, and it may be that the discovery of new material will produce adults of transition stages, which will make generic identification difficult where genera have been made somewhat lavishly. It cannot be assumed that the collections of these Lower Cambrian forms are within measurable distance of completion.

A tentative sub-zoning of the Lower Cambrian is suggested by Walcott, based partly on the known stratigraphical occurrences of the Mesonacidæ in the few rare instances where successive forms exist in the same region, but mainly on the order of development.

D. *Olenellus* Zone (Upper).
C. *Callavia* Zone.
B. *Elliptocephala* Zone.
A. *Nevadia* Zone (Lower).

It will be interesting to find how far this tentative scheme will stand the test of future work. In Europe there are at present no positive facts by which the merits of the classification can be tested, but the series of beds of the Solva type of lithology, which occur in Wales and at Nuneaton in the English Midlands, are suggested as a hunting-ground—we cannot call it a "happy" one—which ought to be exhausted.

Another subject of general interest is the sudden appearance of life in the Cambrian period, which has for long engaged the attention of geologists, and acted as a harmless safety-valve when the impetus to theorize would not be denied. But in the case of the papers under discussion, behind the explanation there is a unique knowledge of the stratigraphical relationships of the Cambrian and pre-Cambrian rocks in North America, coupled with the new light shed on Cambrian stratigraphy by the recent researches of Mr. Bailey Willis and Mr. Blackwelder in China and of H.M. J. Deprat and H. Mansay in Yun-nan. The suggestion that there is an extensive break in the succession between the Cambrian and pre-Cambrian in all known localities, and that the Algonkian deposits are all epicontinental, appears to be the most probable explanation of the sudden appearance of prolific organic life in the Lower Cambrian. However, there

must still remain the reservation that there is room for many important discoveries in the pre-Cambrian sediments; and although the contention may be true in the main, we may still find the progenitors of the Cambrian types in pre-Cambrian sediments situated in favourable localities, i.e. as distant as possible from the centre of the pre-Cambrian shield and beyond the limits of the Algonkian continents.

The present best-known pre-Cambrian fossils are the *Beltina* of the Belt series, but as an interesting supplement to the recent researches of Professor Garwood on the importance of the work of algæ in the formation of the geological record, Walcott describes a series of forms which he compares to the Cyanophyiceæ in the limestones of the Belt series and other Algonkian deposits of the Cordilleran region. Apart from these and a few rather doubtful cases, fossils are conspicuously absent in the pre-Cambrian. At the same time a break appears to exist between the pre-Cambrian and Cambrian in Asia, North America, and Europe. In Eastern Asia, as far as the evidence at our disposal will allow us to speculate, northward transgressive movements seem to occur in Lower and Middle Cambrian times, the transgression being continued into Upper Cambrian times. A similar set of movements are found in North America with minor oscillations and local regressions in Middle Cambrian times. In Europe there is a suggestion of similar conditions, a basal unconformity, a set of shallow water and laterally varying Lower and Middle Cambrian deposits with abundant non-sequences (some parts of the Middle Cambrian are more extensive and suggest open waters, but not deep waters), and an important transgression in the Upper Cambrian. Thus the Cambrian period in all three regions represents a time of great oscillatory transgressive movements culminating in the Upper Cambrian, during which the great Algonkian continents were invaded by shallow seas in which marine faunas thrived and multiplied.

The record of this oscillatory but generally progressive submergence is shown not only by the stratigraphical relationships of the strata, the proved disconformities and overlaps, but appears also in a general survey of the geological provinces of this period. Taking North America and Eastern Asia for example, the Lower Cambrian faunas can be broadly grouped into two main provinces, the North American with *Olenellus*, etc., and the Eastern Asiatic with its peculiar form *Redlichia*. In Middle Cambrian times there are again two broad subdivisions, the Pacific and Atlantic, but the dividing line has shifted eastward into the American continent, and the faunas are more varied as a result of the wider extent of shallow seas. During Upper Cambrian times there is a general merging of the various faunas, and the differentiation into provinces becomes indistinct. The history of the faunas is an indication of the history of their habitat, and this Cambrian record indicates the migration and then the breaking down of barriers, the gradual evolution of a narrow strip of shallow seas on the border of large continents, to an epoch of shallow seas and islands, and finally wide marine areas merging and growing around much diminished continental areas.

NOTICES OF MEMOIRS.

I.—Report of the Committee for investigating the Lower Carboniferous Flora at Gullane.[1]

Consisting of Dr. R. Kidston (Chairman), Dr. W. T. Gordon (Secretary), Dr. J. S. Flett, Professor E. J. Garwood, Dr. J. Horne, and Dr. B. N. Peach.

A NEW discovery of petrified plant-remains was made, in 1914, at a point below high-water mark near Gullane, Haddingtonshire. The place could only be reached at certain states of the tide. In order to accelerate collecting, blasting operations were proposed, and a grant voted at last meeting of the Association to meet the expenses. The locality, however, lies within the area of the Forth Estuary, and, although the military and police authorities readily gave permission to blast on the foreshore, it was considered inadvisable to act on that permission meanwhile. No part of the grant was used therefore, but sufficient material has been collected to amplify considerably the data already obtained. Some 150 thin sections of the material have been prepared and examined.

The flora represented in these sections is as follows :—

Lepidodendron veltheimianum, Sternb.
Stigmaria ficoides, Sternb.
Botryopteris (?) *antiqua*, Kidston.
Bensonites fusiformis, R. Scott.
Pitys primæva, Witham.
Pitys dayii, sp. nov.
Pitys, sp. nov.

Chief importance is attached to the specimens of *Pitys*, as so many well-preserved specimens have never been obtained elsewhere. Many of these examples had the bark preserved, while one of them consisted of a branch tip still clothed with needle-like leaves. Much light has been thrown on the stem structure of the genus, while the details of the connexion of leaf and stem have also been determined.

As regards the other plant types represented, it is interesting to note the similarity between the whole assemblage and the flora of the Pettycur Limestone at Pettycur, Fife. Indeed, the form *Bensonites fusiformis*, R. Scott, has not, so far, been recorded except from Pettycur. Both Gullane and Pettycur lie on the Forth, and the geological horizon of the rocks at both localities is not very different, so that the similarity of the floras is not surprising.

The specimens from Gullane occur in a greyish-white clastic rock, which on examination proved to be a highly decomposed volcanic ash. It is suggested that the decomposition of the ash, by vapours emitted from the volcano during its activity, produced solutions of mineral matter which caused the petrifaction of plant fragments included in the ash. These plant fragments occur quite sporadically through the rock, and they have evidently not been drifted in water. The petrifying solutions have been both calcareous and siliceous, so that some specimens are preserved in carbonate of lime, others in silica, while a few are partly in the one and partly in the other.

The perfection of the preservation is very striking, and it is proposed to continue collecting specimens when possible.

[1] Read before the British Association, Section C (Geology), Newcastle, 1916.

II.—The Palæoliths of Farnham.[1] By Henry Bury, F.G.S.

THE information contained in a previous paper on the same subject (Proc. Geol. Assoc., vol. xxiv, pp. 178–201) is here revised and enlarged. The implements of the Alice Holt Plateau (including Terrace A) are usually large (5 to 8 inches long), and very few are later than the Chellean period. On Terrace B, on the contrary, the majority of unabraded implements are small (3 to 4 inches long), and quite 40 per cent are Acheulean. There are also many flakes, used as scrapers, which may be Mousterian. Terrace C, beyond a few Le Moustier flakes, yields no clear evidence of its age; but it is not impossible that the valley may have been excavated to this depth in early Chellean times. On Terrace D unabraded implements are extremely rare, but among them are a few which may be of Le Moustier age. Another terrace (E) about 20 feet above the river is covered with a thick layer of drift, but has so far only yielded one implement.

REVIEWS.

I.—*Apractocleidus teretepes*: a New Oxfordian Plesiosaur in the Hunterian Museum, Glasgow University. By W. R. Smellie, M.A., B.Sc. Trans. Roy. Soc. Edin., vol. li, pt. iii, 1916.

IN this paper the author gives a very detailed account of the remains of a Plesiosaur collected by Mr. A. N. Leeds in the Oxford Clay of Peterborough. The skull and caudal region are missing, but otherwise the skeleton is nearly complete. In many respects this form is intermediate between *Cryptocleidus* and *Tricleidus*. Thus, in the fore-paddle the humerus articulates distally with the radius, ulna, pisiform, and a small accessory ossicle, as is the case in *Tricleidus*. On the other hand, in the shoulder-girdle the interclavicle is very small or absent, and the triangular clavicles meet extensively in the middle line as in *Cryptocleidus*. For these and other reasons the author has established a new genus for the reception of this form. Many of the characters, however, which are regarded as indicating the higher organization of this type, are certainly merely the result of the great extension of the ossification of the bones consequent upon the advanced age of the individual. Such characters are the extension forward of the scapulæ in advance of the clavicles, and the elongation of the dorsal rami of the scapulæ and of the postero-lateral processes of the coracoids.

This interesting paper is illustrated by nine text-figures and one plate.

[1] Read before the Geologists' Association, December 3, 1916.

II.—The Geology of Ben Nevis and Glen Coe (Explanation of Sheet 53). Memoirs of the Geological Survey, Scotland. By E. B. Bailey, M.A., and H. B. Maufe, M.A.; with contributions by C. T. Clough, J. S. Grant Wilson, G. W. Grabham, M.A., H. Kynaston, B.A., and W. B. Wright, B.A. pp. 247, with 12 plates. 1916. Price 7*s.* 6*d.*

THIS memoir describes the geology of the region that contains the highest mountain and perhaps the wildest and most rugged country in Great Britain. All phases of its geology are replete with interest.

The area is a greatly dissected part of the main Highland plateau, with a summit level of about 3,000 feet. Ben Nevis and other high peaks rising above this level are regarded as features dating from an earlier geographical cycle. Loch Linnhe, lying in a north-easterly direction along the shatter-belt of the Great Glen, divides the area into two unequal parts. Another system of valleys runs W.N.W.-E.S.E.; and these remarkable 'through' valleys, cut athwart the grain of the country, are consequent upon the pre-glacial uplift of the Highland plateau. Glacial erosion is believed to have cut off spurs and thus widened the valleys. In some cases it is responsible for hanging valleys, although general deepening of valleys by ice action is considered improbable. A large part in breaking up the 'through' valleys into segments is attributed to the formation of pre-glacial delta-watersheds or corroms. While accepting many of Professor J. W. Gregory's views as to the origin of fiords, the authors are not inclined to attribute so much potency as he does to earth-movements (gaping faults and joints) in the development of the typical West Highland fiords.

The subject of prime interest in this memoir, however, is the structure and succession of the Highland Schists. These rocks form the basement of the whole district, but are partly covered by extensive outpourings of Old Red Sandstone lavas (Glen Coe and Ben Nevis), and are intruded by great masses of plutonic rocks, principally granite (Ben Cruachan, Ballachulish, Ben Nevis). The Highland rocks consist of alternations of phyllite, mica-schist, and quartzite, with thin horizons of limestone which form good datum-lines for the interpretation of the structure. The folding of the rocks is very complex. Mr. E. B. Bailey has developed the view that the rocks are arranged in a number of great recumbent folds, which are frequently ruptured along fold-faults or slides. In certain cases the major folds have been bent into later secondary folds, and have been dislocated by ordinary faults. In consequence of the extraordinary inversion and repetition the beds have suffered, the original stratigraphical sequence is doubtful, and it is not known which is the top or bottom of the list of formations. As usual, in the interpretation of regions of extreme complexity such as this, differences of opinion arise; and in regard to the Kinlochleven district Mr. Carruthers holds views at variance with those of Mr. Bailey. The chief difficulty appears to be the number of formations recognized by the respective observers. Mr. Carruthers increases the number of stratigraphical horizons and

consequently diminishes the complexity of structure. Without special knowledge of the area it is impossible to decide between the rival views. Mr. Bailey, however, accepts Mr. Carruthers' interpretation as on an equal footing with his own for the district in question, his own view being based on a restricted sequence and greater structural complexity.

The interest of the region is well maintained in the next series of rocks, the Old Red Sandstone lavas which centre about Glen Coe and Ben Nevis. They consist of hornblende-, pyroxene-, and biotite-andesites, with rhyolites, and have been poured out on to a very uneven surface of the Highland schists. The two great areas of lava in this region, although forming the highest ground, owe their preservation to subsidence within great circular faults. One of these encircles the Glen Coe lavas, except on the south, where the fault-line is broken through by the Cruachan granite. Igneous material rose along the peripheral fault during subsidence, but never penetrated to the inner side of the fault plane. The fault intrusion is chilled against the fault plane, and is usually separated from it by a band of flinty crush-rock produced by the friction of the subsiding mass.

Both the larger granite masses of the region show distinct inner and outer portions, of which the former are the younger. They are interpreted as magmas which filled the voids caused by successive cauldron-subsidences. The concentric arrangement of the Ben Nevis granites and lavas is explained in this way. The magmas are believed to have been emplaced largely by the stoping method described by Daly.

The detailed petrography of the Old Red Sandstone igneous rocks is dealt with in a separate chapter. Their composition is illustrated by a fine series of new chemical analyses. There is a useful historical account of the terms granite, granitite, tonalite, adamellite, banatite, granodiorite, etc., but the conclusions adopted as to their scope are open to criticism. Two new rock names, *aplogranite* and *appinite*, have been invented, but their definitions are at once too vague and broad to be of much use. The uselessness of measuring the quantitative relations of the minerals of igneous rocks by the recognized micrometric methods is illustrated by a highly fallacious diagram.

The various granites of the region have produced remarkable metamorphic effects on a great variety of rocks, including schists, sediments, and igneous rocks. These are dealt with in a chapter which is a distinct contribution to the literature of contact metamorphism.

A group of W.N.W. dykes of dolerite, basalt, and monchiquite are regarded as of Tertiary age. A small explosion vent in the Allt Coire na Bá may also be Tertiary. The breccia is invaded by a basic rock which proves to be a fresh nepheline-basalt.

The final chapters deal with the glacial phenomena and with the economic products of the area. Roofing slates and granite are quarried on a comparatively large scale at Ballachulish.

The memoir, which has been edited and mainly written by Lieut. E. B. Bailey, is excellently illustrated by twelve fine plates

and numerous maps and diagrams. The Scottish Survey geologists are to be congratulated on the memorable results of a long, patient, and intricate piece of work.

G. W. T.

III.—Late Pleistocene Oscillations of Sea-level in the Ottawa Valley. By W. A. Johnston. Geological Survey of Canada, Museum Bulletin No. 24; 1916.

ALTHOUGH the attention of British geologists is at the present time mainly directed to economic problems, it is nevertheless very desirable that a paper of such scientific importance as that about to be discussed should be brought to their notice. The author has made a notable contribution to the study of late-glacial changes of sea-level, and the facts he has put on record might almost be said to constitute a complete demonstration of the applicability of the theory of isostasy to these changes.

It will be recalled that this theory ascribes the raised or tilted shorelines which are found around the centres of glacial dispersal to the sinking in of the earth's crust beneath the pressure of the ice-sheets, and its subsequent recovery when the ice has melted away. The depression and recovery were greatest at the centres of dispersal where the ice was thickest, with the consequence that the shorelines are highest near these centres and descend gradually towards the margins of the glaciated districts. Before they reach these margins, however, they invariably pass beneath the present sea-level. There are no late-glacial raised beaches in the peripheral parts of the glaciated districts, the shorelines which were formed during the retreat of the ice from these areas being all beneath the present sea-level. This relation indicates very clearly that the general sea-level must have been considerably lower during the earlier stages of retreat than at the present day, and the same conclusion can be arrived at on *a priori* grounds by considering the effect on the ocean-level of the binding up of enormous quantities of water in the ice-sheets.

We have, therefore, in seeking for an explanation of the late-glacial changes in the relative level of land and sea, two factors to deal with. The first is the isostatic recovery of the earth's crust, the second is the general raising of level of the ocean due to the melting of the ice-sheets. According as the first or second of these factors predominated there occurred either emergence or submergence in the isostatically affected areas.

This appears to be the explanation of the curious fact established by Brögger in the Christiania region, that the first change of level after the retreat of the ice was one of submergence, which, at a somewhat later stage of retreat, gave place to emergence. That this is the course of events to be expected from the interplay of the two factors mentioned is apparent from the following considerations.

1. At the period of deposition of the earlier late-glacial marine deposits from which Brögger drew his conclusions, about one-third to one-half of the total retreat of the ice-margin had been accomplished; and it is roughly at this stage of retreat, when the climate had already considerably ameliorated, and there was at the same time

a large body of ice still in existence, that the most rapid return of water to the ocean is to be expected.

2. Brögger has clearly established that the isostatic recovery progressed with a wave-like motion from south to north along the Cattegat, following up the retreating ice-margin. This seems to indicate that the recovery takes some time to get under way, and does not attain its maximum rate until the neighbourhood is altogether clear of ice.

At this particular period of the retreat, therefore, it would be natural to expect that the rise of the ocean level might be, for a time, faster than the isostatic recovery, and submergence would result. Later, when the isostatic recovery had gathered pace and the amount of water returning to the ocean from the waning ice-sheets had become gradually less, we might expect the isostatic recovery to attain the upper hand and give us progressive emergence.

Now the best test of the validity of this theory is its applicability to the isostatically affected areas of the British Isles and North America. Unfortunately, in the British Isles the highest late-glacial shoreline is only 100 feet above the present sea-level, and within this small vertical range evidence of the kind utilized by Brögger is not to be expected. In North America, until the appearance of the paper under review, no investigation, such as would bring to light a relation of this nature, appears to have been placed on record. Johnston now brings forward evidence, of a nature similar to that adduced by Brögger, to show that the late-glacial changes of sea-level in the Ottawa Valley were precisely the same as those established for the Christiania region, namely, that the sea first rose on the land as the glaciers retreated, and that it was not until a later date that emergence supervened. Moreover, he makes a further point of great importance in establishing the isostatic theory on a firm basis. This point, for which there was no direct evidence in the Norwegian case, is to the effect that the tilting of the Great Lakes region was in progress before and during the rise of the sea in the Ottawa Valley, for, presumably from a consideration of contemporaneous ice-margins, it is concluded that "the Ottawa Valley must have been, in part at least, occupied by the ice-sheet during the existence of Lakes Iroquois and Algonquin, and at least a small amount of uplift affected the region at the foot of Lake Ontario during the life of Lake Iroquois. Uplift also affected the northern portion of the Great Lakes region, and probably included the upper portion of the Ottawa Valley near Mattawa during the existence of Lake Algonquin, and while the ice-sheet still occupied the upper portion of the Ottawa Valley". Further, it is not a case of alternating elevation and depression, "for the results of investigations by numerous geologists, of the raised beaches of the Great Lakes region, has shown that differential uplift took place almost continuously as the ice withdrew."

We thus have direct proof that a district which was rising relatively to those around it was nevertheless undergoing submergence beneath the level of the sea, that in fact the two factors invoked to explain the late-glacial changes of level were in action simultaneously in the same region.

There is now but one thing wanting to make the analogy between the isostatic phenomena of America and Europe perfect in every detail, and that is the discovery of a shoreline corresponding to the 'early Neolithic' or 'Littorina-Tapes' raised beaches of Great Britain and Scandinavia. This should represent in the south a distinct resubmergence, and in the north a pronounced check or slowing down in the general emergence.

We must congratulate the author of the paper under review on having made a striking advance in Quaternary geology. Is it too much to hope that he will carry his researches further, and complete the history of the changes of level in his district down to the present day?

W. B. Wright.

IV.—Thirty-sixth Annual Report of the Director of the United States Geological Survey to the Secretary of the Interior for the year ended June 30, 1915. pp. 186, with 2 coloured plates. Washington, Government Printing Office, 1915.

BY its very reticence and conciseness this slender volume is eloquent testimony to the extensive and multifarious character of the work carried on by the United States Geological Survey. How large and useful are the services it renders may be gathered from the following extract from the opening page of the report itself: "The recognition by citizens generally that the Geological Survey is a bureau of information as well as a field service has gradually placed upon it a large burden of work as well as of responsibility. The amount of correspondence involved in performing this public duty may be indicated by the fact that approximately 50,000 letters of inquiry were handled in the different scientific branches of the Survey last year. The scope of these inquiries is not less noteworthy, for they range from requests for information concerning the geology of every part of the United States or the water supply, both underground and surface, of as widely separated regions as Alaska and Florida, or for engineering data on areas in every state in the Union, to enquiries regarding the natural resources of foreign countries, especially those of Central and South America." So large has the Survey grown that for convenience of administration it is divided into six main branches, each of which is subdivided into various divisions, certain of which are further subdivided into sections. First and possibly foremost of them comes the Geologic Branch, which is responsible for the geological work of the Survey. Though it was primarily formed for the comparatively restricted task of the classification and examination of the public lands reserved to the state, its scope has been extended to the preparation of a geological map of the whole of the United States. The nature of its duties is best set forth in the words of the Report: "At present the geologic branch is not only the effective agency of the Survey in the geologic investigations carried on by the Government in all parts of the United States and Alaska but also the great geologic information bureau to which the American public, from Key West to Point Barrow and from San

Diego to Eastport, applies for knowledge of every sort concerning the earth's crust and its mineral constituents. To the people of this country and, in a surprising degree, to the citizens of other countries, the Survey is the principal source of geologic information regarding not only the geology of the United States and its possessions but also that of Mexico, Central America, and even South America. Through its correspondence it is asked for data regarding the geology and mineral deposits of all parts of the world. The geologic branch has therefore the double task of geologic surveying, including the investigation, description, and mapping of the geology and mineral deposits of all parts of the country, the classification of the public lands, and the publication of the results of its work on the one hand, and of furnishing to the public miscellaneous geologic information derived from all sources on the other." The Geologic Branch is divided into four divisions, viz. geology, Alaskan mineral resources, mineral resources, chemical and physical researches, which though working on independent lines yet co-operate effectively with one another. We read that the scientific staff of the division of geology at the beginning of the year consisted of 66 geologists, 33 associate geologists, 26 assistant geologists, 15 junior geologists, and 22 geologic aids, a total of 162. It must further be remembered that besides the Federal Survey many, if not all, the States have their own Bureaus of Mines and Geological Surveys, and much of the field-investigation and palæontological research has been conducted in connexion with the local staffs. In order to secure uniformity in the geological names the question is considered by a standing committee of the branch, the secretary of which scrutinizes the nomenclature and classification in all manuscripts submitted for publication. The work of the division of chemical and physical research is not wholly confined to the customary routine analyses, but includes many investigations of considerable scientific interest. The division of mineral resources is responsible for that valuable annual return entitled "Mineral Resources of the United States"; upon its preparation no fewer than sixty persons are wholly or partly engaged.

The Topographic Branch is engaged on geodetic work, and up to date has mapped 40·2 per cent of the entire country; its skilled staff numbers 159. One of the most important objects of the work carried on by the Water Resources Branch is the investigation of underground water with the view of the irrigation of arid areas; the skilled staff numbers 76.

The fourth Branch, viz. the Land Classification Board, which was the origin of the Survey, collates the results of the investigation of public lands made by the branches already mentioned. Since the classifications required by the public lands laws fall into two broad groups, depending upon the presence or absence of mineral deposits or of water respectively, the Board is divided into two divisions, the one for mineral and the other for hydrographic classification. Last of all we have the Publication and Administration Branches. The total expenditure on the whole Survey amounts to nearly one and a half million dollars.

This is not the place to discuss at length the points suggested by

this Report or the lessons for ourselves that may be drawn from it, and we shall confine ourselves to a brief paragraph. There is much to be said for establishing an institution to serve a similar purpose for the British Empire—an institution which should ever be ready to explore outlying and little-known quarters of the Empire, and to investigate and report upon their resources, and which should cordially co-operate with and encourage the local geological surveys. Something has already been done, and perhaps as the result of these tragic days something more may eventuate; we have at least been thoroughly taught the danger of depending solely upon the result of haphazard individual effort. At the Imperial Institute there is a small staff under the Colonial Office to undertake investigations of the kind in point, with particular reference to the Crown Colonies. Very useful work has been turned out, but all on too small a scale: the staff is not large enough, and the financial equipment far from generous or sufficient. Geological surveys exist at home and in the great dependencies: all work independently and without mutual co-operation. In Great Britain the Geological Survey, which—perhaps humorously—is placed under the Board of Education, has devoted itself to investigations of some scientific interest, but appears to have carefully avoided the risk of being reproached with doing anything which might prove of economic value. Only under the stress of war has it so far broken through its traditional aloofness from mundane affairs as to issue a series of monographs on the mineral resources of the United Kingdom. A small and distinct Survey is maintained in Dublin. To complete the picture of heterogeneity it only remains to add that the actual working of mines comes within the purview of the Home Office.

V.—Petroleum and Natural Gas Resources of Canada. By Frederick G. Clapp and others. Vols. I and II. Canada, Dept. of Mines, Mines Branch No. 291.

THAT the various members of the British Empire are alive to the extreme importance of the question of liquid and gaseous fuel is shown by the recent activities of the government departments of the chief self-governing Colonies in investigating their natural resources of oil and gas. Canada, whose oil industry dates back as far as 1857 and whose gas industry has now far outstripped the former in value, and is growing enormously, has rendered a service to the oil investigator in the publication of two volumes on Petroleum and Natural Gas Resources of Canada, which, in addition to a series of general chapters on Petroleum problems, combine in a very accessible form the available knowledge on the various fields, and include a series of useful maps.

The first of the volumes deals with general oil and gas problems, geological, chemical, engineering, and economic, and the composite authorship gives it this advantage, that the various subjects have each been considered by investigators and workers in the particular branch; thus we are spared the anomaly of the geologist writing on engineering or the engineer writing on geology, with the usual

unfortunate results. It would have been preferable to include more of the Canadian element in the authorship, for certainly in the first volume the writers appear only at their ease when citing examples from the United States, but as a general treatise on petroleum vol. i will probably find a much wider circle of readers than those interested in Canadian oil-fields. In it are collected what is really a series of essays on petroleum problems, some of them but mediocre, a dull restatement of well-trodden ground, but others distinctly fresh and well-balanced, with clear concise wording where descriptive, and full of suggestive ideas where theoretical. It would probably have been of advantage to omit most of the first chapter, for to summarize the world's oil occurrences in thirty pages, country by country, is to attempt the impossible and to involve the bewildered student in a labyrinth of dead place-names.

Chapter ii contains much useful physical and chemical data, while under the heading "Geological Occurrence of Petroleum and Natural Gas", chapter iv, there is a clear and short account of the various theories of the production of natural hydrocarbons, in which the author safely joins both sides of the warring camps of the upholders of organic origin. But the remarks on oil migration do not break any fresh ground, and here unfortunately the need is most lamentable. There comes a time in the history of all theories when a few adverse storms are necessary to unsettle the fallacies which take root so easily and to orient ideas to fresh facts. It is a pity that the current ideas of oil migration have lived so long in the belt of calms, for, strange as it may seem when considering the importance of the subject, we do not yet know how, when, why, or how far an oil will migrate. Gravitation, capillarity, different specific gravity of water and oil (and some authors concede gas pressure) are the sum-total of the admitted agents on migration, yet it is doubtful whether any one of these has any primary effect on the initial movements of the oil, and it is just these which are so important. Gravitation in the accepted sense of the migration theorist requires free pore-space for downward motion, but water-borne sediments will certainly be water-clogged in their finer deposits. Capillarity will cause oil to migrate in fine dry deposits, but it is a movement from the larger pore-space to the smaller, not from the fine deposit to the coarse, and in addition there is the same difficulty that the sediments will almost certainly not be dry. The differential specific gravity of water and oil will have its expected result in the proper conditions, i.e. where the pore-space is large enough to allow a certain limited circulation of liquids, but the hydrocarbons originate in the fine-grained deposits, and it is just this initial migration from the fine deposits to the contiguous coarse deposits wherein lies the difficulties with the present theoretical ideas. When, however, the secondary processes which take place in argillaceous sediments immediately after deposition are examined, and the gradual diminution of pore-space during compacting, with its necessary out-pressing of water and other liquids, is taken into account, it is evident that here is a very potent factor in the expulsion of liquids from fine material which is easily compacted to coarse material which is more resistant to

pressure. There is no doubt that the effect of earth stresses, as apart from the pressure of the overburden, will have similar results.

Turning now to the chapter on drilling, the 103 pages devoted to this subject are an extremely useful summary of the methods of drilling, dealing with the matter in a way which adds interest to a subject which is usually not very entertaining. The conservation of oil and gas resources is another subject of striking importance.

Vol. ii contains a description of the oil-fields of Eastern and Western Canada. In Eastern Canada the more important points of interest are the recently developed gas-field of New Brunswick, and the possible resources in oil shales in the same province. Ontario is still the chief oil and gas producer, but of recent years Alberta has been coming to the fore with a rapid increase in gas production. In this province the hydrocarbons are obtained from the Cretaceous Sandstone, at an horizon approximating to the Dakota sandstone. In Athabaska and contiguous regions there are the extensive outcrops of asphaltic sands, the so-called "Tar Sands", while farther north in the Mackenzie River region wide untapped areas are awaiting further development.

V. C. I.

VI.—Principles of Oil and Gas Production. By Roswell H. Johnson and L. G. Huntley. pp. 371. John Wiley & Sons. Price 16*s.* net.

THE geological aspect of the occurrence of petroleum and natural gas is by no means overburdened with explanatory textbooks, and although the volume under discussion deals in addition with other branches of the oil industry, a large proportion of its pages is devoted to geological considerations. To the European student it is also welcome inasmuch as it emphasizes the essentially American aspect of the subject, but the widespread occurrence of natural hydrocarbons in the American Palæozoic leads the authors into dangerous generalizations. Thus it produces the assertion that "it is probable that a considerable production will some day be developed in the older formations when they have been thoroughly prospected in Europe and Asia"; but it must be remembered that the conditions of occurrence of the Palæozoic rocks in the Central United States have not their counterpart on this side of the Atlantic, although Asia may produce many similarities. On the other hand, the long chapter on the Oil and Gas Fields of North America is distinctly good, and the chapters dealing with Oil and Gas Reservoirs and the Migration and Accumulation of Oil and Gas, although necessarily short, contain the germs of very suggestive ideas.

It is a distinct relief to get away from that obsession for anticlines which has of recent years somewhat obscured the vision of many oil-field geologists. To such an extent has this hypothesis been taken, that on several oil-fields the converse process of reasoning has been adopted and the presence of the oil been regarded as sufficient proof of the occurrence of the anticline. It is by no means suggested that the anticlinal occurrence of oil and gas is not of great importance, but the promulgation of the idea of its exclusive

importance is to be deprecated, while the beautifully simple diagrammatic representation of the successive occurrence of water, oil, and gas in the arched strata is at its best but a crude and partial statement of the whole story.

The tendency of modern investigation has been to prove that the original nidus of the hydrocarbons is the fine-grained sediments, and that the migration into the coarser and permanently more porous horizons takes place at an early stage as the result of compacting. Many of these porous horizons are quite limited in their lateral extent, so that the later migration as a result of tilting and folding movements is often limited, unless abnormal conditions such as faults and joints produce planes of egress for the gas or oil. Hence it is found that as a result of variations in porosity and of irregular deposition of sandy horizons, the primary migration due to compacting is often of more importance in the differentiation of oil into pools than the later earth movements, which merely localize the oil and gas in the higher portions of the more porous strata. Of course, in many cases, the coarse horizons are sufficiently widespread to allow the anticlinal hypothesis to hold, but the reverse is more common in nature than is usually suspected.

V. C. I.

VII.—Geology and Ore Deposits of Rossland, British Columbia. By Charles Wales Drysdale. Memoir 77 of the Geological Survey. Ottawa, Government Printing Bureau, 1915. pp. xiv + 317, with 6 maps in pocket, 25 plates, and 26 figures in the text.

THE rich district of Rossland, which is situated in the Trail Creek mining district of the West Kootenay district of British Columbia, about 6 miles west of Columbia River and 5 miles north of the International Boundary, produces gold, silver, and copper. It was discovered in 1890, and has been worked continuously since 1894. In this memoir the region is very fully described. The geological features and the mineral enrichment, which present many points of interest, are discussed in some detail. The district appears to have been covered by sea during at least part of the Carboniferous age, and upheaved at the end of the Palæozoic era. An intrusion of augite porphyry occurred during the Triassic period, and at the close of the Jurassic period the rock formations were invaded by the Trail granodiorite batholith, this being the first period of mineralization. Erosion took place throughout Cretaceous times, and at the end the whole Cordillera was uplifted and the present ranges were outlined. The second main period of mineralization occurred in Miocene time. During the Pleistocene a change to a glacial period took place. The ore consists of pyrrhotite, chalcopyrite, pyrite, and marcasite, with a little arsenopyrite, molybdenite, and bismuthinite, in a gangue of altered country rock, containing some quartz and locally a little calcite. The deposits resemble in many respects the well-known ones at Namaqualand, Cape Colony, and possess some structural features in common with those at Butte, Montana.

VIII.—United States Survey: Rhode Island Coal.

In Bulletin 615 of the U.S. Survey, Mr. George H. Ashley gives an account of Rhode Island Coal, the interest of which is mainly economic, the conclusion being drawn that the coal cannot compete with that produced by New England and Pennsylvania. The coal has an unusually large range, character, and quality, varying from anthracite to graphite, and contains a high percentage of ash and moisture. The coal beds, which were originally of moderate thickness, have been so folded and compressed that, while in places large pockets have been formed, elsewhere they have been nearly altogether squeezed out. The coal ignites slowly and with difficulty, and makes so hot a fire as to destroy stove tops and furnace linings.

REPORTS AND PROCEEDINGS.

I.—The Royal Society.

November 2, 1916.—Sir J. J. Thomson, O.M., President, in the Chair.

"On the Photographic Spectra of Meteorites." By Sir William Crookes, O.M., F.R.S.

Thirty rare earthy meteorites, mostly acquired through the courtesy of the British Museum Trustees, have been examined.

The paper first deals with a few novel features in the construction of the spectrograph. The instrument has a train of five double quartz prisms of the Cornu type, and an explanation of their action in preventing double refraction is given. The jaws of the slit are formed of transparent quartz prisms, cut and mounted in such a manner that the edges appear opaque to light. A device, called the *fixed slit system*, is described, by which all uncertainty caused by variation in the width of the slit in various experiments is removed. The aerolites were all examined for occluded gases, especially with negative results for any inert gases that might be present. The spectrum tubes showed only compounds of hydrogen, carbon, and sulphur, and a little free hydrogen. The arc spectrum of each aerolite has been photographed from the region of the ultra-violet to the end of the visible.

The aerolite was powdered, mixed with powdered silver of known purity, and formed into a cake by hydraulic pressure. This gives sufficient cohesion for manipulation and enables it to conduct the current. The resulting spectrum contains, in addition to the lines of the aerolite constituents, only those due to silver, which are comparatively few. Examples of these spectra were exhibited.

All the lines given in the arc spectra of the thirty aerolites have been identified, and were shown in the spectrum photographs. The examination has revealed the presence of unexpectedly large traces of chromium in all the specimens, a condition quite different to that found in the siderites or meteoric irons, where chromium is practically absent.

The proportion between chromium and nickel remains constant in twenty-six out of the thirty aerolites, and is clearly shown in the photographs. In three only nickel is almost absent.

From the experience gained it has been possible to make a mixture containing known quantities of nickel and chromium, which with the addition of iron produces a spectrum in the neighbourhood of the chromium group that is practically identical with that produced by the aerolite *Aubres*.

II.—Zoological Society of London.

November 21, 1916.—Dr. S. F. Harmer, M.A., F.R.S., Vice-President, in the Chair.

"On the development from the matrix of further parts of the skeleton of the *Archæopteryx* preserved in the Geological Department of the British Museum (Natural History)."

Dr. B. Petronievics and Dr. A. Smith Woodward, F.R.S., V.P.Z.S., read a paper on some new parts of the pectoral and pelvic arches lately discovered in the London specimen of *Archæopteryx*. The coracoid bone most closely resembles that of the ratite birds and the Cretaceous *Hesperornis*. The pubic bones are twice as long as the ischia and meet distally in an extended symphysis, gradually tapering to a point, which seems to have been tipped by a mass of imperfectly ossified cartilage.

III.—Edinburgh Geological Society.

November 15, 1916.—Professor Jehu, Vice-President, in the Chair.

The following papers were read:—

1. "A New Locality for Triassic Reptiles, with Notes on the Trias found in the Parishes of Urquhart and Lhanbryde, Morayshire." By Mr. William Taylor, J.P., Lhanbryde.

Mr. Taylor recorded the discovery, in sandstones about a mile north of the village of Urquhart, of a nearly complete specimen of *Telerpeton*, somewhat smaller than the example described by Huxley in 1866.

On account of lithological resemblances he correlated the sandstones, etc., of Bearshead, Stonewells, Meft, Lhanbryde, and New Elgin with the fossiliferous rocks of Lossiemouth and Spynie, and concluded that the Trias of Morayshire was much more extensive than formerly supposed.

The paper was illustrated by a map showing the distribution of the Triassic rocks in the area extending from Lossiemouth and Bearshead southwards to New Elgin and Lhanbryde. On the map were recorded the genera of reptiles found at the various fossiliferous localities.

2. "Volcanic Necks in North-West Ayrshire" (with lantern illustrations). By G. V. Wilson, B.Sc., H.M. Geological Survey.

The area between Dalry, Ardrossan, and Largs contains the sites of about thirty volcanoes. In the north the large volcanic centre of Misty Law is most probably of Calciferous Sandstone age, and gave rise to the lava-flows of that period in the district. The area to the south is studded with a number of volcanic necks, all of which contain ash of a type similar to the interbedded ashes which occur about the position of the Dalry Blackband Ironstone; it was suggested that some of the necks gave rise to these beds of ash. One neck was

described in which occurred a fallen mass of a coal-seam which had been large enough to work; fragments of charred wood and rounded pebbles of biotite, hornblende, and augite also occur in this neck. In another case marine shells—of a type not later than Millstone Grit—had been found in the ash of a neck, probably washed into the crater of a submarine volcano or into one on low-lying ground liable to submergence. This phase of volcanic activity probably started soon after the deposition of the Lower Carboniferous Limestones, and continued intermittently till Millstone Grit times, with quiescence during the deposition of the Coal-measures; but farther to the south we have the remains of great volcanic activity during the Permian. It was suggested that the district at its period of volcanic activity may have resembled, in some ways, the San Franciscan Volcanic Field of Arizona.

IV.—Geological Society of London.

1. *November* 22, 1916.—Dr. Alfred Harker, F.R.S., President, in the Chair.

The following communication was read:—

"Characeæ from the Lower Headon Beds." By Clement Reid, F.R.S., F.L.S., F.G.S., and James Groves, F.L.S.

The investigations here recorded have been made at Hordle Cliffs (Hampshire), where the strata, below the superficial gravel, belong entirely to the Lower Headon Beds, and consist of freshwater and brackish-water (more or less calcareous) deposits, laid down apparently in wide shallow lakes and lagoons. Such habitats are the most favourable to the growth of Characeæ, and several of the beds have yielded numerous remains of these plants.

There is a great diversity in the fruits of *Chara* found, representing evidently a number of species, belonging to several different sections or genera. With the exception of a few, which are possibly abnormal variations, the fruits can be roughly grouped under the following types:—

I. Tuberculate series. (Type of *C. tuberculata*, Lyell = *Kosmogyra*, Stache, emend.)
   (*a*) Spherical.
   (*b*) Obovoid or pyriform, with distinctly prolonged base.

II. Non-tuberculate series.
   (*c*) Large spherical, diam. *c.* 1 mm. (type of *C. medicaginula*, Brongn.).
   (*d*) Large ellipsoidal (type of *C. helicteres*, Brongn.).
   (*e*) Medium-sized, subglobose, tapering more or less at both ends.
   (*f*) Cylindric-ellipsoidal, showing more numerous striæ.
   (*g*) More or less pyriform: that is, definitely tapering towards the base.
   (*h*) Minute, subglobose-ovoid (long. = *c.* 350 to 500 μ).

It is difficult to determine the exact number of species found, on account of the extreme variability of some of the forms, but the authors consider that at least twelve may, for the present, be conveniently treated as distinct.

The vegetative remains are comparatively few, consisting of minute portions of stems and branchlets of different diameters, and these it is impossible at present to connect with any particular types of fruit.

Though investigations of some earlier formations have shown that there are extinct forms of Characeæ exhibiting important points of difference from their living representatives, the remarkably distinct and characteristic oogonium of five elongated spirally twisted cells has remained constant certainly as far back as the Inferior Oolite, and it is only in earlier formations that any doubt arises as to whether bodies are or are not *Chara* fruits.

Characeæ are found in still fresh or brackish water all over the world, under widely different conditions as regards heat, etc., and may therefore be expected to occur in almost all freshwater formations.

For these reasons it is suggested that the fruits of this group of plants, when more widely collected, may prove of considerable value as zonal fossils for the correlation of lacustrine deposits lying in isolated basins. Doubtless, on account of their small size, the Characeæ have in the past often been overlooked.

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2. *December* 6, 1916.—Dr. Alfred Harker, F.R.S., President, in the Chair.

Mr. G. C. Crick, A.R.S.M., F.G.S., gave an account of some recent researches on the Belemnite animal. He stated that it was not his intention to deal that evening with the homologies of the Belemnite shell or with the phylogeny of the Belemnite group, but to confine himself to the restoration of a typical Belemnite animal and its shell, as shown particularly by examples in the British Museum collection.

He first demonstrated, by means of a rough model, the construction of the Belemnite shell, including the guard or rostrum, the phragmocone with its ventrally situated siphuncle, and its thin envelope the conotheca, with its forward prolongation and expansion (on the dorsal side) known as the pro-ostracum. He then exhibited photographic slides of examples in the British Museum collection showing these various characters, and noted the abrupt termination of the chambered cone on the lower part of the pro-ostracum, of which the dorsal surface may have been partly or almost completely covered by a thin forward extension of the guard. To illustrate what was known of the complete body of the animal as found associated with the guard, he then showed photographic slides of two of the examples figured by Huxley in his *Memoir on the Structure of the Belemnitidæ* published in 1864. Each of these exhibited the guard associated with portions of the pro-ostracum, the ink-bag, and the hooklets of the arms. The form of the hooklets with their thickened bases was discussed, this feature in a great measure justifying the attribution to the Belemnite of certain Cephalopod remains (found practically at about the same geological horizon) that included uncinated arms associated with an ink-bag, and frequently also with nacreous portions of (presumably) the pro-ostracum.

Of the remains of uncinated armed Cephalopods from the Lias, each exhibiting the same form of hooklets as those figured by

Huxley, he said that the British Museum collection contained seventeen examples, all from the neighbourhood of Lyme Regis and of Charmouth, in Dorset. Each specimen exhibits a number of uncinated arms associated usually with an ink-bag, sometimes also with nacreous matter, and in two instances also with the guard or rostrum. These two examples were those to which he had already referred as having been figured by Huxley, and unfortunately the arms are not well preserved in either of these specimens; in one (*B. bruguierianus*, from the Lower Lias near Charmouth) there are only a few scattered hooklets, while the arms of the other (*B. elongatus*, from the Lower Lias of Charmouth) are represented only by a confused mass of hooklets. Of the other fifteen examples, in one there are a few solitary hooklets; in another the number of the arms is very indistinct; in two the remains of only two arms are preserved; in one there are traces of three arms; in two there are indications of three, or possibly four, arms; in one there is a confused mass of possibly four arms; and in one there are the remains of four, or possibly of five, arms. In each of the remaining six specimens six arms can be more or less clearly made out, while there is not a single example in which more than six uncinated arms are displayed.

Of the six examples that exhibit six uncinated arms four are stated to be from the Lias of Lyme Regis; one is from the Lias of Charmouth; and one was obtained from the Lower Liassic shales between Charmouth and Lyme Regis. From a consideration of these specimens, the speaker concluded that the Cephalopod represented by these uncinated arms is the animal known as the Belemnite, and that the six uncinated arms were arranged in three pairs of unequal length, of which the longest pair was lateral, the medium-sized pair probably dorsal, and the shortest pair probably ventral. He considered the presence of tentacular arms to be doubtful. These observations were in accord with those of Huxley, who, in his *Memoir* already cited, stated that he had "not been able to make out more than six or seven arms in any specimen, nor has any exhibited traces of elongated tentacula, though the shortness of the arms which have been preserved would have led one to suspect their existence".

Mr. Crick regarded certain markings sometimes to be seen on the guard as indicating that during the life of the animal the guard was almost, if not entirely, covered by the mantle, in which case it was highly improbable that the guard was pushed into the soft mud of the sea-bottom in order to act as an anchor.

He considered the animal to have been a free swimmer, swimming forward ordinarily, but when desirable, capable also of sudden and rapid propulsion backwards.

V.—Liverpool Geological Society.

1. The first meeting of the fifty-eighth session of this Society was held on October 10 last, Mr. J. H. Milton, F.G.S., F.L.S., President, occupying the chair. The report on the work of the past session

showed that in spite of present adverse circumstances there had been a slight increase in the membership, and that the activities of the Society had been well maintained.

The President in his annual address dealt with "The Coral Types of the Carboniferous Limestone", and gave a very valuable and helpful résumé of the principal diagnostic characters of the different genera. The lines of their evolution were traced, and their value as zonal indices clearly shown. In this connexion a warm tribute was paid to the work of the late Dr. Arthur Vaughan. The address was fully illustrated by a beautifully drawn series of sections of the chief types, and an excellent collection of specimens from North Wales and elsewhere.

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2. *November* 14, 1916.—J. H. Milton, F.G.S., F.L.S., President, in the Chair.

The following paper was read:—

"The Pebbles of the Middle Bunter Sandstones of the Neighbourhood of Liverpool." By T. A. Jones.

The author described the results of an investigation into the nature of the rock types represented amongst the pebbles, which he roughly classified under the following heads: Quartzites and Grits, Granites, Mica Schist, Felstones, Tourmaliniferous Quartzites, Grits, Schists, etc., Fossiliferous Pebbles, and Miscellaneous. Attention has been given chiefly to those bearing tourmaline, which collectively were present in greater abundance than those of any other group, with the exception of the Quartzites and Grits. The mineral was present in great variety and quantity, and on the whole the rocks showed marked similarity to those surrounding the granite masses of Devon and Cornwall, with which they were perhaps still more strongly linked by the discovery of a pebble of granite containing abundant tourmaline in slender prisms, and small pinkish garnets. This rock when crushed yielded splintery fragments of dark indigo blue tourmaline, closely resembling those found amongst the heavy density minerals of the finer material of the Triassic sandstones of the district. A light ash-grey friable schist was also described, which contained irregular grains of brown and blue tourmaline apparently of clastic origin, which was also considered competent to have furnished some of them.

Three other varieties of biotite granite were found, two of them with micropegmatitic structure. Twelve varieties of felstones had been examined, all of acid type. Four contained tourmaline plentifully, and two seemed to be tuffs rather than lavas. Among the fossiliferous pebbles one of reddish quartzite containing a single specimen of a small *Orthis* was recorded, the only example so far known to the author from the local pebble beds.

On the whole the assemblage of pebbles seemed substantially identical with those of the Midlands as described by Professor Bonney, although the tourmaliniferous group was judged to be of greater importance. The paper closed with a brief discussion of the possible sources of the pebbles, and the method of transport.

3. *December* 12, 1916.—J. H. Milton, F.G.S., F.L.S., President, in the Chair.

Mr. H. C. Beasley and Professor J. W. Gregory, D.Sc., F.R.S., were unanimously elected honorary members. Mr. Beasley has been an ordinary member for the last forty-six years, during which period he has been one of its foremost working members, and it has been a great pleasure to his fellow-members to recognize his great services to the Society and to local geology.

The recent announcement of the gift of a Chair of Geology to Liverpool University by Professor and Mrs. Herdman, as a memorial to their son, was referred to with much interest and sympathy, and the following resolution was approved: "That this Society has learned with much satisfaction of the intended establishment of a Chair of Geology in the Liverpool University, and has special pleasure in the fact that the establishment is due to the generosity of one of its members and past presidents, Professor Herdman, and Mrs. Herdman, by whose action the long-felt need for the due recognition of this subject in the University scheme will at length be satisfied."

Mr. C. B. Travis, in a "Note on Terminal Curvature at Billinge Hill", described an interesting example to be seen near the summit of the hill, where the outcropping beds of the Lower Coal-measures are curved over in a remarkable manner by the onward pressure of the Irish Sea ice-sheet invading the district from the west. This section has not previously been described.

Mr. F. T. Maidwell followed with an account of recent geological rambles about Liverpool, in which he threw fresh light on some old sections. The correlation of the coal-seams in the collieries at Neston, Cheshire, was dealt with at some length, also the little-known outcrop of Permian strata at Skillaw Clough near Bispham.

VI.—The Wellington, New Zealand, Philosophical Society (Geological Section).

The annual meeting of the Wellington Philosophical Society (Geological Section) was held last evening, September 20, 1916, at the Dominion Museum. Mr. G. Hogben, C.M.G., F.G.S., presided. The Annual Report stated that during the year seven meetings had been held, with an average attendance of fourteen. The following papers have been read: "A Phase of Shore-line Erosion," by Mr. J. A. Bartrum; "Terminology for Foraminal Development in Terebratuloids," by Mr. S. S. Buckman, F.G.S.; "The Continental Shelf" and "The Motion of Water in Waves", by Dr. C. A. Cotton, F.G.S.; "The Geological Occurrence and Origin of Petroleum," by Messrs. W. Gibson and M. Ongley; "The Structure of the Paparoa Range," by Dr. J. Henderson; "An Artesian Trial Bore at the Westshore, Napier," by Mr. R. W. Holmes; "Notes of a Visit to Marlborough and North Canterbury," by Mr. P. G. Morgan, F.G.S.; "Stage Names applicable to the Divisions of the Tertiary in New Zealand," by Dr. J. A. Thomson, F.G.S.; "The Volcanic Rocks of Oamaru," by Mr. G. Uttley, F.G.S.

The election of office-bearers for the ensuing year resulted as follows: Chairman, Dr. C. A. Cotton, F.G.S.; Vice-Chairman, Dr. J. Henderson; Hon. Secretary, Mr. E. K. Lomas; Committee, Messrs. Morgan, F.G.S., Ongley, Uttley, F.G.S., Holmes, and Dr. Thomson, F.G.S.

During the evening Dr. J. Allan Thomson read papers: (1) "On the so-called 'Drift Formation' of Hawera"; (2) "The Geology of the Middle Clarence Valley, between the Bluff and Herring River." —*New Zealand Times*, September 21, 1916.

OBITUARY.

CLEMENT REID, F.R.S., F.L.S., F.G.S., Etc.

Born July 6, 1853. Died December 10, 1916.

It is with the deepest regret that we have to record the death of Mr. Clement Reid, late of H.M. Geological Survey, which took place at his residence, One Acre, Milford-on-Sea, on Sunday, December 10. He was buried at Milford on the following Wednesday. Mr. Reid was so deeply versed in all matters relating to the later Tertiary and more recent strata that all geologists interested in these deposits will feel that their science has lost a master and they a reliable co-worker. Only those who knew Mr. Reid intimately could appreciate his sterling abilities and intense devotion to his scientific work, characteristics in which he so much resembled his great-uncle Michael Faraday.

Mr. Clement Reid joined H.M. Geological Survey in 1874 and started work, under the able guidance of H. B. Woodward, in the South-West of England, but in 1876 was transferred to Norfolk, and there began, under the same genial leader, the detailed study of the Pliocene and Pleistocene deposits, including the "Forest Bed" and "Contorted Drifts", of the Norfolk coast. The name of Clement Reid has ever since been intimately connected with the study of these formations; indeed, in all matters relating to the "Norfolk Forest Bed" and the nearly associated strata he was regarded as the chief authority. His memoir on *The Geology of the Country around Cromer* (Explanation of Sheet 68 E.), together with the maps and sections, is a model of careful work, and exemplifies the close attention to minute details as well as the broad grasp of his subject which has ever characterized his scientific work.

Mr. Reid published numerous papers on geological subjects, many of which are of more than ordinary interest; but as an officer of H.M. Geological Survey his chief work was the preparation of maps and of explanatory memoirs, and for this purpose after leaving Norfolk he was engaged in later years in Yorkshire, Lincolnshire, Sussex, Hampshire, Isle of Wight, Dorset, Wilts, Cornwall, and the London area. It is therefore in the publications of the Survey that the bulk of Mr. Reid's work will be found, and these chiefly relating to Tertiary and more superficial deposits.

Whatever Mr. Reid undertook to do he did thoroughly. He was